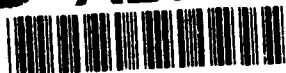


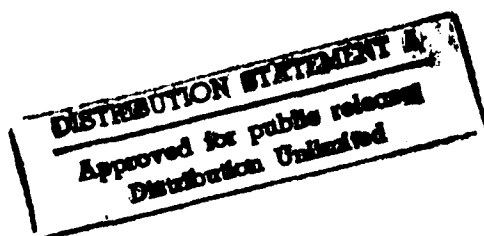
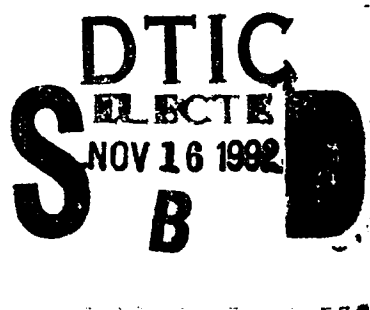
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British Military Requirements, Resources, and Conventional Arms Control

Joseph E. Nation



RAND

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British Military Requirements, Resources, and Conventional Arms Control

Joseph E. Nation

January 1990

Prepared for the
United States Army
United States Air Force

RAND

PREFACE

This report was prepared for two RAND projects: "Alternative NATO Futures," sponsored by the U.S. Army's Training and Doctrine Command, and "Enhancing the Allied Contribution to Tactical Airpower in NATO's Central Region," sponsored by the U.S. Air Force's Deputy Chief of Staff for Plans and Operations. These projects were performed jointly under the National Security Studies program entitled "The Future of Allied Tactical Airpower in NATO's Central Region," for the Arroyo Center and Project AIR FORCE, two of RAND's federally funded research and development centers.

The report compares the financial requirements of modernizing British military forces with a range of budgetary resources both with and in the absence of negotiated conventional force reductions in Europe. Most of the research for this report was undertaken during a period of rapid change in Europe. It is highly speculative in nature, resting on several significant assumptions about an extraordinarily uncertain future in Europe. It is in no way connected with official U.S. government assessments on the subject. The analysis focuses on the evolution of economic and demographic constraints on long-term British defense planning, projects resource-requirement imbalances, and examines potential reactions to imbalances. It should be of interest to those concerned with developing concepts and force structures for NATO missions in the early 21st century, allied modernization efforts, and conventional arms reductions in Europe.

The British Ministry of Defence reviewed and provided written comments on an earlier version of this report. The Ministry chose not to comment in detail, and it does not concur with the report's findings. In particular, the Ministry reported that its own internal costings, which have not been made available to RAND, did not support the conclusion that substantial defense budget shortfalls may occur in the medium or long term. The Ministry of Defence also emphasized that no consideration is being given to reductions in British modernization efforts, readiness, or defense commitments in the absence of conventional arms control agreements.

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SUMMARY

British military leaders will face a formidable challenge in the next 15 years as they modernize their forces. The financial requirements of modernization efforts are certain to be large, particularly since replacement equipment is almost always more costly than its predecessors. Modernization requirements appear substantial even with conventional force reduction agreements that cut forces deeply.

Compounding factors complicate Britain's military modernization efforts. Demographic pressures will probably make recruiting Britain's all-volunteer force both more difficult and more costly. Increasing personnel costs in turn may reduce defense resources available for investment and jeopardize the acquisition of replacement equipment. A reduced Warsaw Pact threat will also probably reduce defense resources.

This report compares the financial requirements of achieving British modernization goals with a range of projected budgetary resources. The financial requirements of major equipment production with projected resources are estimated in two cases: in the absence of conventional arms control in Europe, and following a Conventional Forces in Europe (CFE) agreement.

In the absence of conventional arms control agreements, the estimated production costs of British equipment modernization between 1990 and 2005 would be £38 billion, based upon current estimates. (Some accounting adjustments result in slight decreases in requirements.) A range of feasible production cost growth, 0 to 8 percent, is used to estimate probable future costs. Annual cost growth of 5 and 8 percent leads to substantially higher cost estimates of £48 and £57 billion, respectively. More than 40 percent of these totals result from Royal Navy modernization requirements.

To forecast major equipment production resources in the absence of arms control, first, aggregate defense budget growth is based on defense budget share of Gross Domestic Product (GDP), constant defense spending over time, and the defense budget's share of total government expenditures. Demographic and other budgetary and economic data are analyzed to forecast likely growth in areas of the national budget that compete with the Ministry of Defence (MoD) for funds.

Nondefense expenditures are unlikely to force reductions in long-term defense spending; however, in a low resource scenario, historical defense budget expenditure data suggest a potential 1 percent per year decline in real defense expenditures. In a high resource scenario, defense budget share of GDP should increase at an annual rate of 2 percent. In a middle expenditure scenario, the defense budget should increase at an average annual rate of 1 percent.

A model for British defense spending uses historical data to project available funding levels for specific budget categories, including the production of major equipment items. Major equipment production resources should fall between £10 and £30 billion from 1990 to 2005 based on defense budget growth of -1 percent and +2 percent per year, respectively.

Conventional arms control agreements in Europe will reduce Britain's modernization requirements and defense resources, and requirements and resources are adjusted based on a CFE agreement. Requirements may fall about 10 percent. Requirements under CFE are

projected between £39 and £42 billion. British defense budgets under a CFE agreement are assumed to increase at the rate of 1 percent per year. Under these assumptions, resources are projected for the production of major equipment items at £27 billion from 1990 to 2005.

Finally, requirements are contrasted with resources as estimated by the defense budget model. In the absence of arms control, the middle requirement–middle resource case results in a £22 billion shortfall. A low requirement–high resource case results in a £5 billion shortfall, and a high requirement–low resource case results in a £42 billion shortfall. These figures represent the difference between major equipment production resources and requirements. The sea category (roughly corresponding to the Royal Navy) appears to be the most underfunded based on projected shortfall to production share ratios.

Equipment shortfall figures represent the difference between major equipment production resources and requirements and understate additional increases in aggregate defense spending necessary to pay for variable expenditure categories in the budget model. Defense budget shortfalls may be as much as four and one-half times greater than major equipment shortfalls. (This multiplier effect reflects the structure of the defense budget model, which includes several variable expenditure categories, greatly increasing the difference between major equipment production and defense budget shortfalls. Excluding some variable expenditure categories reduces the multiplier effect.) **In the middle case, the budget shortfall is £101 billion, or 32 percent of aggregate spending during the 1990–2005 period.** In the high requirement–low resource case, the aggregate defense budget shortfall is £186 billion, representing a 66 percent budget shortfall. In the low requirement–high resource case, an approximate £22 billion shortfall is projected, representing 6 percent of aggregate spending.

Considerable shortfalls persist when requirements are compared with resources in conventional arms control scenarios. A CFE I (first-stage reductions) agreement reduces defense budget shortfalls in a middle case from 32 percent (estimated in the absence of arms control) to between 17 and 21 percent. (Lower defense budget increases, possibly more likely following a CFE agreement, result in larger shortfalls.) In short, a CFE agreement will reduce British modernization requirements, major equipment, and defense budget shortfalls; however, **CFE will not eliminate shortfalls.** Further reductions in requirements, such as those discussed in subsequent CFE negotiations (commonly referred to as CFE II and III), increases in resources, or both, may be necessary to avoid future shortfalls. In fact, **without reductions in requirements or efficiency gains, aggregate defense spending may have to increase at slightly more than 3 percent per year to eliminate shortfalls.**

CFE II and III may reduce Britain's military requirements and may eliminate shortfalls; however, this again depends on aggregate defense resources. While objectives for future CFE negotiations have not been determined, CFE II equipment and personnel reductions of 25 percent and flat aggregate defense budgets eliminate shortfalls. CFE III reductions of 50 percent and flat aggregate defense budgets, of course, result in budget surpluses. However, it is unlikely that defense budgets will remain flat as the perceived threat of war in Europe declines, and potentially large shortfalls may persist even if requirements fall sharply.

Substantial budget shortfalls may force MoD planners to make difficult choices, ranging from stretching out procurement purchases to potentially more drastic measures, including reductions in readiness or curtailing the level of effort in some missions. Increased efficien-

cies, particularly decreases in personnel and operating costs, may reduce the need to take such drastic action. Similarly, reductions across nondefense budget categories by central planners in the Ministry of the Treasury may lessen the need for such action.

Efficiency savings, particularly reductions in personnel and operations expenditures, mitigate modest budget shortfalls. Similarly, stretching out equipment purchases reduces shortfalls considerably and is a likely MoD response, as is a combination of these measures. More drastic measures, probably less likely to occur, including reductions in mission commitments and readiness, may be necessary if shortfalls are not remedied by efficiency gains or equipment stretchouts. There will undoubtedly be great resistance to such actions; however, should they occur, further reductions in the Royal Navy's surface fleet are the most likely option.

Efficiency gains, stretching out equipment purchases, readiness reductions, or marginal reductions in Britain's military commitments in conjunction with a CFE I agreement eliminate most projected shortfalls. For example, reductions in equipment and personnel requirements of about 10 percent (as outlined in CFE I), efficiency gains of a similar magnitude, and modest delays in the in-service dates of new equipment will probably eliminate shortfalls if defense budgets remain stable in real terms. Deeper reductions as outlined in CFE II and III and a combination of efficiency gains and modest delays in the in-service dates of new equipment may eliminate shortfalls even if the defense budget decreases slightly in real terms.

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I. INTRODUCTION

BACKGROUND

British military leaders will face a formidable challenge in the next 15 years as they modernize their forces. In the Army, Royal Air Force (RAF), and Royal Navy (RN), leaders plan to replace or to upgrade large numbers of combat and support equipment with new and more costly systems. In the Army, for example, replacements for virtually all armored vehicles, including Chieftain main battle tanks, are planned. The RAF's recent acquisition of Tornado aircraft reduces its future modernization requirements, although Phantom, Buccaneer, and Jaguar aircraft are scheduled for replacement. The Royal Navy, in addition to its acquisition of Trident nuclear-powered ballistic missile submarines (SSBNs), plans to replace roughly 80 percent of its attack submarines and 85 percent of its major surface combatants.¹ The financial requirements of these modernization efforts are certain to be large, particularly since replacement equipment is almost always more costly than its predecessors. Modernization requirements will be substantial even with conventional force reduction agreements that cut forces deeply.

Compounding factors further complicate Britain's modernization efforts. Demographic pressures, in particular a shrinking number of potential young service personnel, will make recruiting Britain's all-volunteer force both more difficult and more costly. Increasing personnel costs in turn may reduce defense resources available for investment and jeopardize the acquisition of replacement equipment. A reduced Warsaw Pact threat will also probably reduce defense resources and compound modernization efforts.

Britain's commitment to a strong defense and to NATO cannot be questioned. For example, Britain's defense spending share of gross national product has consistently been greater than that of any other Central Europe NATO member. Similarly, Britain's military forces continue to be well regarded in terms of capabilities, readiness, and equipment. However, Britain's ability to achieve its modernization objectives in light of these increasing economic, demographic, and political pressures is uncertain.

Identifying Britain's modernization objectives and assessing Britain's ability to meet these objectives is important in any immediate future scenario. First, Britain will continue to play a critical role in NATO.² Changes in Britain's objectives or level of commitment to NATO may affect NATO strategy and would be a key concern to U.S. and other policymakers.

Second, identifying Britain's modernization objectives permits U.S. and NATO long-term planners to coordinate military and weapon acquisition strategies. This results in a more efficient use of scarce defense resources and permits long-term planners to carefully orchestrate changes in strategy in advance.

¹These figures reflect the Royal Navy's objective of maintaining current force structure and are based on estimated retirement rates of current equipment.

²The British Army of the Rhine (BAOR) contributes the First British Corps to NATO's Northern Army Group (NORTHAG) and provides a key element of NATO's forward defense. The RAF, in addition to forces in Britain, stations 16 combat squadrons in Germany and performs strike/attack, air defense, and other critical missions. The RN assists in protecting Atlantic supply routes and provides almost 80 major combatants in NATO's maritime strategy.

If Britain appears unlikely to meet its modernization objectives, assessments increase in importance. Accurate assessments permit U.S. and other NATO planners to react in a timely manner to uncertainties in the planning process and to more effectively coordinate long-term NATO policies.

APPROACH

This report compares the financial requirements of achieving British modernization goals with a range of projected budgetary resources. The financial requirements of major equipment production and projected resources are estimated in two cases: in the absence of conventional arms control in Europe, and following Conventional Forces in Europe (CFE) agreement.

- The study identifies major equipment and financial requirements necessary to meet modernization objectives.
- An analysis is presented of historical defense budget data and aggregate economic trends to establish a range of likely defense budget resources.
- The study develops a model of the British defense budget to project future resources for major equipment requirements.
- The financial requirements of major equipment modernization are compared with projected resources for such items and possible British reactions to imbalances are examined.

STRUCTURE

Section II focuses on military modernization requirements and objectives to the year 2005. It identifies missions and major equipment assets of British armed forces today and estimates current replacement equipment production costs. Section III forecasts a range of aggregate defense budget resources. Section IV offers a model of the British defense budget and projects future financial resources available for the production of major equipment items. Section V examines the effects of conventional arms control agreements on requirements and resources. Section VI compares major equipment production requirements with a range of major equipment production resources and estimates aggregate defense budget shortfalls both in the absence of conventional arms control agreements and in the presence of conventional arms control agreement in Europe. The final section explores potential reactions to shortfalls and offers conclusions.

II. BRITISH MILITARY EQUIPMENT AND THE COSTS OF MODERNIZATION

This section describes British defense missions, outlines major equipment¹ and equipment retirement rates, and reports Ministry of Defence plans² for equipment modernization over the next 15 years. *It does not include adjustments to modernization plans resulting from an arms control agreement in Europe.* It also estimates current production costs of major equipment to compare these with projected major equipment resources in Sec. IV.

British military missions are to a great degree determined by the evolution of previous commitments.³ Current missions and strategy reflect this evolution, although specific missions today are described in former Secretary of State for Defence John Nott's 1981 defence review.⁴ Nott's review broadly outlined the major missions of the Army, Royal Air Force, and Royal Navy and Marines (RN/M)⁵ and restated Britain's commitment to NATO. (95 percent of Britain's defense spending is devoted to NATO-related missions.) In the absence of any future formal "defence review,"⁶ these broadly outlined missions should change only marginally. Such marginal changes will result from "first order assumptions" that the Secretary of State for Defence provides service commanders in each budgetary cycle.

ARMY

Missions

Army missions include the BAOR's role in NORTHAG, homeland defense, and out-of-area operations. The central focus of the British Army remains its commitment to central Europe and its Corps operations in NORTHAG,⁷ including antitank operations, air defense, and offensive support. For more than 30 years, the British have maintained a force of at least 55,000 troops in the FRG. The BAOR maintains three armored division headquarters, seven armored brigades, and one air-mobile brigade in peacetime; the total troop commitment to central Europe would increase to more than 150,000 in a conflict as forces from England reinforced those in Germany. Reinforcement includes an infantry battalion and supporting equipment available to NATO's Supreme Allied Commander for deployment on either the northern or southern flanks and the U.K. Mobile Force (UKMF) for deployment to the Baltic Approaches.

¹Equipment assets in early to mid 1989.

²Publicly available MoD and Parliamentary data are used when possible; however, unofficial sources or my own estimates were sometimes used. In these cases, assumptions and sources are explicitly noted.

³See Greenwood and Hazel, 1977, for an overview of commitments to 1976.

⁴*The United Kingdom Defence Program: The Way Forward*, 1981.

⁵One major change established by the Nott review was the reduction from three to two ASW carrier groups and the eventual phase out of amphibious support ships. These decisions were reversed in the aftermath of the Falklands conflict.

⁶A formal defence review in the near future seems unlikely since reviews are politically unpopular and are viewed as an acknowledgment of defense management failure.

⁷NATO was founded in 1949, although subsequent agreements in 1952, 1954, and 1957 between the FRG and the U.K. established specific troop commitments under the command of the Supreme Allied Commander. Degenhardt, 1986.

The expansion of the Territorial Army to six infantry battalions would form much of the British Army's homeland defense. Territorial Army and Army reservist troops would be assigned to reinforce existing units. Finally, the Army supports British military operations in Northern Ireland, Gibraltar, Hong Kong, and the Falkland Islands.⁸

Equipment

The Army has announced several important modernization programs for the 1990s and early 2000s. Table 1 illustrates current and replacement equipment, as well as their estimated production replacement costs.

A large share of Army modernization requirements center around replacing Army armored fighting vehicles (AFVs), many of which were produced in the 1950s.⁹ The FV432, which constitutes the bulk of the Army AFV inventory, was produced between 1963 and 1971. Some near-term requirements will be filled by recent Saxon and Warrior orders, but in the long term, the Army must replace older AFVs. The Army hopes to undertake an ambitious program to build as many as 5000 AFVs, designated Future Families of Light Armored Vehicles (FFLAV), which will perform multiple roles, including transport, command and communications, and light assault.¹⁰

Substantial changes are also planned for main battle tanks. The MoD is now studying several options for the replacement of its Chieftain tanks, including upgraded Challengers, the German-produced Leopard 2, and the U.S. M1A1. Figure 1 illustrates the projected composition of AFVs, including main battle tanks.

The Trigat program should result in more capable antitank guided weapons to replace Milan and Swingfire. Milan systems were upgraded in 1984, although against increasingly capable Soviet tanks in the 1990s and early 2000s they are suspected to be inadequate. Trigat long-range (LR) weapons will also be capable of helicopter launch.

Lynx and Gazelle antitank helicopters will most likely be replaced in the late 1990s with the Light Attack Helicopter (LAH), although a weapons upgrade is due shortly. The MoD has not announced a follow-on replacement to Lynx and Gazelle, neither seems likely to continue to operate beyond the mid to late 1990s.¹¹ The LAH has not entered the development phase, although that is expected in the next several years.

Army surface-to-air missile (SAM) modernization will continue with the introduction of Rapier B2 and Rapier 2000 systems. Rapier B2 will enter service in the next few years, while the Rapier 2000 should become operational between 1992 and 1994. Army efforts to upgrade air defense assets closely parallel RAF efforts. Starstreak, a hand-held system and the next step in Blowpipe and Javelin's continuing upgrades, has been funded since 1986 and entered service in 1989.

⁸The commitment to Hong Kong will terminate in 1997.

⁹About 1100 Ferret AFVs were produced between 1952 and 1971. Most of the older models have probably withdrawn from service; nevertheless, the average age is probably around 25 years. See *Jane's Weapon Systems*, 1988.

¹⁰*Jane's Defence Weekly*, 1987. Foss, 1989, reports a 7,000 FFLAV effort.

¹¹This retirement date corresponds with announced retirement rates of RAF Wessex and Puma at about 15 years. The dozen or so recently delivered Lynx AH.7s should operate into the early 2000s.

Table 1
MAJOR BRITISH ARMY EQUIPMENT
(Millions of £1987)

Current Equipment	No.	Average Age	Replacement Equipment	No.	IOC ^a	Unit Production Cost	Total Cost ^b	Costs, 1990-2005
Helicopters								
Lynx, Gazelle	269	13	Light Attack Helicopter (LAH)	300 ^c	1995	1.5 ^d	450	450
Antitank Guided Weapons (ATGW)								
Milan	NA ^e	13 ^f	Trigat medium range (MR)	3000 ^g	1995	NA	300 ^h	300
Swingfire	NA	19	Trigat long range (LR)	3000	1997	NA	NA	NA
SAMs								
Blowpipe/Javelin	NA	10	Starstreak	NA	1989	NA	700	300
Rapier	120	18	Rapier 2000/B2	120	1992	NA	2000 ⁱ	1850
Battle Tanks								
Challenger	250 ^j	4	NA	NA	NA	1.5	280	150 ^k
Chieftain	500 ^l	17	Leopard 2, M1A1, Challenger 2	500 ^m	1992	2.5 ^m	1250	1250
AFVs								
FV432 AFV	2400	21	Warrior/Saxon/FFLAV ^p	2400	1988	1 ^q	2400	1920
Ferret AFV	1100	31	Warrior/Saxon/FFLAV	1100	1998	1	1100	1100
Scorpion AFV	270	14	FFLAV	270	1997	1	270	270
Fox	200	14	FFLAV	200	1997	1	200	200
Saxon	200	4	None	NA	NA	NA	NA	NA
Spartan	200	4	None	NA	NA	NA	NA	NA
Scimitar FV-107	300	3	None	NA	NA	NA	NA	NA
Artillery								
175 mm M107 artillery	36	NA	MLRS	NA	1990	NA	410	245
105 mm artillery	220	NA	ADP Bates	NA	1992	NA	200	200
155 mm howitzers	173	8 ^r	undesignated ^s	NA	1992	NA	250	250
TOTAL COSTS								£8485

SOURCES: Unless otherwise indicated, information based on author's estimates; *Jane's Weapon Systems*, 1988; Defense Marketing Service, 1988, 1989; International Institute for Strategic Studies, 1988; and selected *Statement on the Defence Estimates*. Includes assets of the Territorial Army unless otherwise indicated.

^aInitial operational capability, or in-service date.

^bSome numbers are rounded.

^cIncludes attrition purchase for Alouette, Scout, and Beaver helicopters currently in service.

^dBased on Lynx AH.7 price.

^eNA denotes not available or not applicable.

^fUpgraded in 1984.

^gArbitrary division between MR and LR.

^hAuthor's estimate for both MR and LR based on a £400 million program cost. This is an optimistic estimate given U.K. development share costs alone of £300 million. *Jane's Defence Weekly*, 1988h.

ⁱIncludes RAF Rapier production costs.

^jIncludes 17 training vehicles.

^kAssumes payment not yet made on final 100. *Jane's Defence Weekly*, 1988c.

^lExcludes Territorial Army units.

^mWitt, 1989, reports a purchase of up to 600.

ⁿEstimates based on Defense Marketing Service; *Jane's Defence Weekly*, 1988a; and Daly, 1988. Daly reports an M1A1 production unit cost proposal of £2.5m.

^pAbout one-third of FV432 and Ferret will be replaced by Warrior and Saxon. The remainder will be replaced by FFLAV or other AFVs.

^q*Jane's Defence Weekly*, 1987. The *Statement on the Defence Estimates*, 1988, cites an approximate £1 billion cost for equipping 13 battalions (1053 Warrior units) with Warrior AFVs.

^r*Jane's Defence Weekly*, 1988.

^sKemp, 1988.

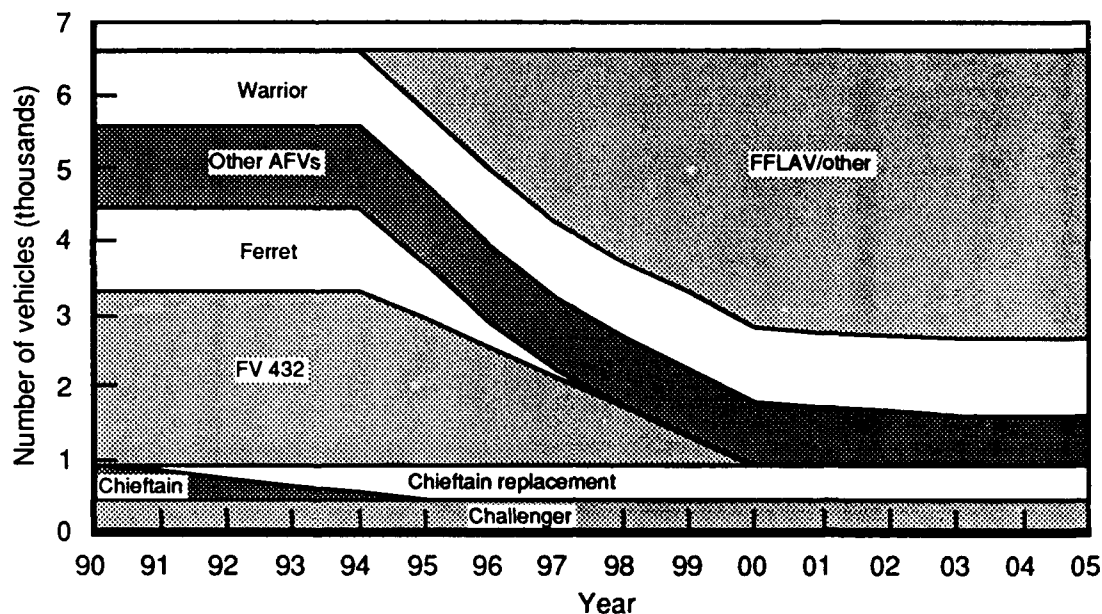


Fig. 1—Army armored vehicles

Finally, the MoD plans to modernize its artillery inventory. The Multiple Launch Rocket System (MLRS 1) should be operational in the early 1990s, replacing the 175 mm M107 gun. Other improvements include ADP Bates 155 mm artillery and possibly the Phoenix Remotely Piloted Vehicle (RPV) in both the reconnaissance and attack roles.

ROYAL AIR FORCE

Missions

The RAF performs four broadly defined defense missions: air defense, maritime and ground strike and attack, transport, and helicopter support.¹² A large share of RAF resources are devoted to homeland air defense and air defense in NATO's central region. The RAF utilizes a layered homeland air defense with Phantom and Tornado F.3 aircraft providing both long- and short-range coverage against attacking bombers and cruise missiles. Bloodhound SAMs provide coverage at medium distances, while Rapier SAMs provide short-range coverage.

¹²Transport missions include strategic and tactical airlift for all services, transport for the Royal Family, and various small types of aircraft for other VIP transport. Helicopter support includes tactical support of Army and Royal Navy forces and search and rescue operations. The RAF also provides strategic reconnaissance and electronic countermeasure (ECM) capabilities, although the assets for these missions are limited.

A large portion of RAF assets are devoted to maritime and ground strike and attack missions.¹³ These include Tornado, Jaguar GR.1, and Harrier GR.3 aircraft assigned to the Second Allied Tactical Air Force (2 ATAF) in the FRG. Buccaneer S.2 aircraft perform maritime strike and attack missions.

A host of other RAF missions, including transport, strategic reconnaissance, and search and rescue are performed by various other aircraft in the RAF inventory.

Equipment

The composition of RAF aircraft and other major equipment assets will undergo several changes in the near future. Table 2 illustrates current and replacement equipment, as well as their estimated replacement costs.

Air Defense

Tornado F.3 and Phantom F-4 aircraft provide the mainstay of the current aircraft air defense inventory, although Hawk aircraft equipped with AIM-9L Sidewinders provide a modest increase in capabilities.¹⁴ Shackleton Airborne Early Warning (AEW) aircraft will be replaced beginning in 1991 by eight Boeing E-3 Airborne Warning and Control Systems (AWACS). The introduction of additional Tornado F.3 aircraft will result in a modest increase in air defense capabilities from 10 in 1988 to 12 tactical aircraft squadrons.

In the late 1990s and early 2000s, the EFA is scheduled to replace all remaining Phantoms in the air defense role. The RAF plans to purchase 250 EFA aircraft, of which perhaps 150 will be devoted to the air defense mission.¹⁵ This should be sufficient for five air defense squadrons. Additional tankers, perhaps Tristars, may replace remaining VC10s as they near 35 years average age. SAM improvements are also scheduled. These include a Rapier point defense upgrade and "M-SAM," a collaborative NATO project.

Strike and Attack

Currently, the RAF's ground attack mission is dominated by nine all-weather Tornado GR.1 squadrons, although Harrier and Jaguar squadrons provide a daytime ground attack capability for closer-range missions. Tornado squadrons also perform nuclear strike missions with gravity weapons.¹⁶ Jaguar aircraft provide tactical reconnaissance, although in the future Tornado aircraft will perform this mission.

Buccaneer aircraft provide maritime strike and attack capabilities, although the age of the Buccaneer fleet makes it unlikely that they will remain in service beyond the mid 1990s.

¹³It would be more appropriate in a detailed description of RAF missions to break this category down into seven separate missions: air interdiction, offensive counter air, battlefield air interdiction, close support, tactical reconnaissance, maritime attack, and nuclear strike. In the interests of brevity, I have combined these categories.

¹⁴Hawk aircraft will probably begin to be retired by the early to mid 1990s. Earlier retirement may occur sooner since Hawks add only marginally to British air defense capabilities. Cost concerns may also lead to early retirement.

¹⁵As Table 2 notes, this is a somewhat arbitrary division of the total aircraft purchase.

¹⁶Standoff nuclear weapons delivered by Tornado are planned for future missions. Miller, 1989a.

Table 2
MAJOR RAF EQUIPMENT
(Millions of £1987)

Current Equipment	Squadrons/ Numbers ^a	Average Age	Replacement Equipment	Squadrons/ Numbers	IOC ^b	Unit Production Cost ^c	Total Cost	Costs, 1990-2005
Air Defense								
F-4 Phantom	7/145 ^d	18 ^e	Tornado F.3	4/145 ^f	1989	19.5 ^g	1840	500
			European Fighter Aircraft	5/150 ^h	2000 ⁱ	24 ^j	3600	3600
Tornado F.3	3/71	1	None	NA ^k	NA	NA	0	0
Shackleton AEW	1/10	31 ^l	E-3 AWACS	1/8	1991	127	1015 ^m	790
Tristar L-1011 K.1	1/6	10	None	NA	NA	NA	NA	0
VC10 K.2/3	1/9	22	None ⁿ	NA	NA	NA	NA	0
Bloodhound SAM	3	23	M-SAMP ^p	3	1995	NA	1065 ^q	1065
Rapier SAM	6	17	Rapier 2000 ^r	6	1993	NA	1640 ^s	1520
Attrition purchases	0/5	NA	Tornado F.3	0/15	1994	19.5	295	295
Sub-total								£7770
Strike/Attack								
Tornado GR.1	9/220 ^t	4	None	NA	NA	NA	NA	0
Buccaneer S.2	2/60	21 ^u	undetermined ^v	2/47	1995 ^w	19.5 ^x	915	915
Nimrod MR.2	4/31	17	None	NA	NA	NA	NA	0
Harrier GR.3	3/97 ^y	11 ^z	Harrier GR.5	3/96 ^{aa}	1988	13.5 ^{bb}	1270	300 ^{cc}
Jaguar GR.1, R.1	4/70 ^{dd}	12	European Fighter Aircraft	2/100	1998 ^{ee}	24 ^{ff}	2400	2400
			Tornado R.1	2/40	1991	19.5	0 ^{gg}	0
Attrition buys	NA	NA	Tornado GR.1	26	1994	19.5	505	505
Sub-total								£4120
Support Aircraft								
Chinook	3.5/57 ^{hh}	6	EH-101 ⁱⁱ	3.5/57	1998	4.9 ^{jj}	280	280
Puma	3/55	15	EH-101 ^{kk}	3/55	1991	4.9	270	245
Wessex	1.5/41 ^{ll}	15	EH-101	1.5/41	1992	4.9	200	200
Wessex SAR	1/18	15	EH-101 ^{mm}	1/18	1992	4.9	90	90
Sea King SAR	1/19	6	EH-101/PP-1	1/19	1998	4.9	95	95
			VC10/Tristar/ other	0/5 ⁿⁿ	1998	15	75	75
VC10 transport	1/16 ⁿⁿ	16 ^{pp}	undesignated	4/45	1995	20 ^{rr}	900	900
C-130 transport	4/45	20	None	NA	NA	NA	0	0
Canberra PR.1	1/11	29	None	NA	NA	NA	0	0
Miscellaneous ^{ss}	NA	NA	NA	NA	NA	NA	100	100
Sub-total								£1985
TOTAL COSTS								£13,875

SOURCES: Unless otherwise indicated, information based on author's estimates; *Statement on the Defence Estimates*, 1988, 1989; Defense Marketing Service, 1988; and Hatch, 1987.

NOTES TO TABLE 2

^aExcludes Operational Conversion Units (OCUs) and training units unless otherwise indicated. Also excludes Hawk squadrons. SAM entries report squadrons only.

^bInitial operational capability, or in-service date

^cSome numbers are rounded.

^dIncludes approximately seven aircraft at Squadron #23 in the Falkland Islands.

^eBurns, 1984.

^fAs noted in the text, replacement by Tornado F.3 results in an increase of air defense squadrons since three F.3 squadrons are operational currently.

^gAviation Advisory Service, 1983, estimates a £36 million (FY87) program unit cost. Unit production costs are estimated at £19.5 million. Recent *Statement on the Defence Estimates* indicate an approximate £25 million program (development and production) unit cost.

^hAssumes 25 aircraft per squadron.

ⁱAssumes an initial production run of the EFA ground attack variant.

^jMost EFA production cost estimates range from £6-7 billion. This assumes the lower figure. Evans, 1987; Beyers, 1988. Others cite higher estimates. For example, Witt, 1988, and Politi, 1988, cite production cost estimates of up to £10 billion.

^kDenotes not available or not applicable.

^lChartres, 1985.

^mIncludes Nimrod shut-down costs of approximately £100m, eight E-3 aircraft.

ⁿThe high ages and flying hours indicate a possible replacement before 2005. These aircraft were produced between 1962 and 1964.

^oAlternatively designated the SA/SAN-90 or MFS-2000. Purchased for the RAF in the Land procurement category. Follow-on to the Hawk. Eight nations have agreed to a one year study. Cook, 1988.

^pBased on French and German shares of project. Total British program costs estimated at £1.4 billion.

^qPurchased for the RAF in the Land procurement category.

^rEstimated £2 billion production and development cost.

^sExcludes Tactical Weapons Training and Tri-national Training Units.

^tAllward, 1981.

^uProbably replaced by additional Tornado procurement, although other schemes, including Nimrod and 767, possible. *Milavnews*, 1979, 1982.

^vHouse of Commons Defence Committee, 1985.

^wAviation Advisory Service, 1983.

^xExcludes Harrier squadron in Belize. Some GR.3 variants may remain in service into the late 1990s. A total of 37 Harriers had been delivered by June 1989. Aviation Advisory Service, 1989b.

^yMason, 1983.

^{aa}Air Pictorial, 1988a.

^{bb}Based on MoD estimates of £1100m program costs for 62 aircraft. Development estimated at 24 percent of program cost.

^{cc}Assumes full disbursement on 21 of original 62 aircraft only before 1990.

^{dd}An additional 30 in storage. Aviation Advisory Service, 1987.

^{ee}Assumes ground attack variant initial production run.

^{ff}See RAF air defense entry for cost data.

^{gg}Assumes funds fully dispersed.

^{hh}Includes some out of area forces. For this reason, helicopter squadron numbers may not correspond with those in the most recent *Statement on the Defence Estimates*.

ⁱⁱSpeculative, although EH-101 procurement seems likely given previous orders. In the short term, Chinooks will be upgraded. See Miller, 1989c.

^{jj}Air Pictorial, 1987 estimates a £300 million package for 25 EH-101s, 16 Lynx (£1.75 million each), and 16 Sea Kings (£4.1 million), resulting in an approximate £4.9 million EH-101 production unit cost. The eagerness to purchase EH-101 might result from a desire to lower program unit costs. Fixed EH-101 development costs are estimated at £450 million. A larger buy would decrease program unit costs. See Aviation Advisory Service, 1986.

^{kk}Air Pictorial, June 1987. The EH-101 will replace Pumas, which will replace Wessex in the short-term.

^{ll}Includes some out of area forces.

^{mm}Speculative, although seems likely given EH-101 replacement of RN Wessex SAR assets.

ⁿⁿIncludes three Tristar and 13 VC10 aircraft.

^{oo}Does not include Tristars.

^{pp}Based on VC10 age.

^{qq}Based on the costs of similar aircraft.

^{rr}Small aircraft, VIP transport, etc. Assumes no training aircraft required.

Nimrod patrol aircraft support the Buccaneer mission and also aid in antisubmarine warfare (ASW) missions.

Modernization of ground strike and attack assets is nearly complete and few changes will occur in the near term,¹⁷ although Harrier GR.5 aircraft have begun to replace Harrier GR.3 aircraft.¹⁸ There are no current announced plans to replace Buccaneer aircraft, although there is speculation that this role will be carried on by the procurement of additional Tornado aircraft equipped with Sea Eagle antiship weapons. The RAF plans to replace Jaguar aircraft in the mid to late 1990s with EFA. No replacement for Nimrod patrol aircraft is likely until well after the turn of the century. Figure 2 illustrates the future composition of RAF air defense and strike/attack aircraft.

Support

Equipment requirements for RAF helicopter, strategic and tactical transport, strategic reconnaissance, and ECM aircraft are substantial, although their replacement costs are modest. The RAF provides helicopter support for all armed services, including five search and rescue squadrons and nine logistical support squadrons.¹⁹ Wessex and Sea King heli-

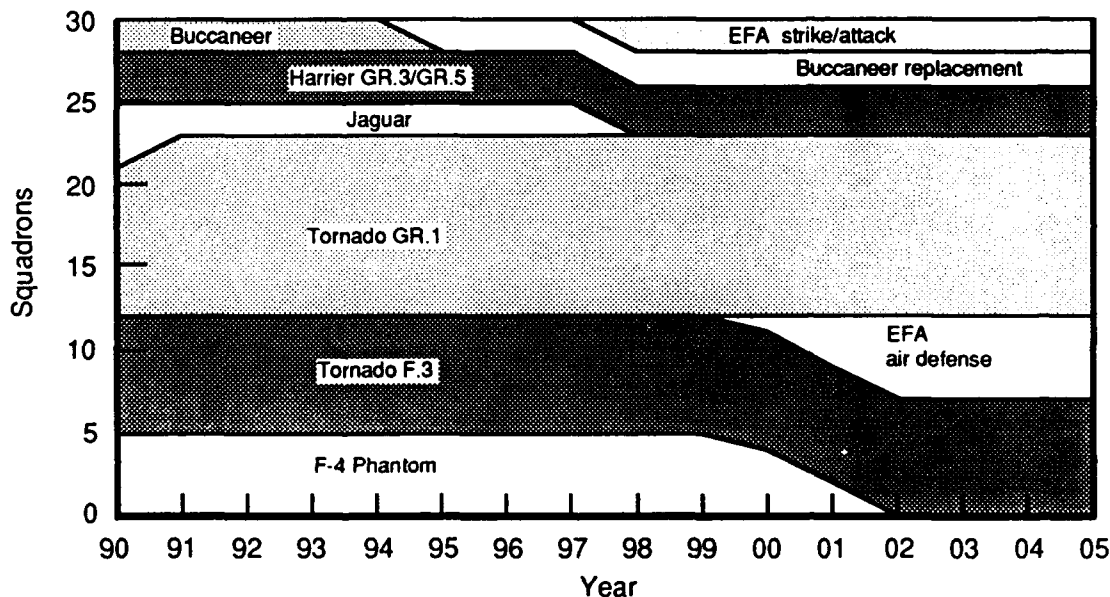


Fig. 2—RAF air defense and strike/attack aircraft

¹⁷A mid-life upgrade is scheduled for GR.1 aircraft in the early 1990s. Improvements include night vision capability, advanced target designation for laser-guided munitions, and other avionics improvements. See Walker, 1987.

¹⁸Some GR.3 variants may remain in service into the 1990s, given their young ages. In the long run, the MoD may consider the Small Agile Battlefield Aircraft (SABA) or another Vertical Short Takeoff and Landing (VSTOL) in the close air support role to replace Harrier GR.5s, although this will probably not occur before 2005. For an overview of SABA, see Brown, 1987. For recent SABA developments, see Finnegan, 1989.

¹⁹Some squadrons perform more than one mission, which explains the discrepancy between this figure and Table 2.

copters perform search and rescue missions, while Chinook, Puma, and Wessex helicopters provide logistical support.

VC10 and Tristar aircraft provide strategic transport, and Hercules aircraft serve as tactical transport. Four squadrons of Canberra aircraft perform strategic reconnaissance and ECM missions.

The RAF plans a modest modernization of helicopter, transport, and other equipment assets in the next 15 years. The RAF soon plans to replace Puma and Wessex tactical squadrons with EH-101 helicopters.²⁰ However, there are no other specific plans for aircraft in this category. Nevertheless, the RAF will probably replace Hercules and Canberra in the medium term and perhaps Chinook, Sea King, and VC10 transport aircraft in the longer term.

ROYAL NAVY AND MARINES

Missions

The Royal Navy (RN) and Marines perform five missions: nuclear deterrence, antisubmarine warfare, surface escort and patrol, support of amphibious assault, and homeland protection, including minesweeping and patrol.

Since 1967 four Polaris SSBNs have performed Britain's nuclear deterrence mission.²¹ Beginning in about 1994, the Royal Navy will begin to replace Polaris with Trident SSBNs.²²

The Royal Navy has clearly begun to place a greater emphasis on its ASW mission and Britain's role in NATO's forward maritime strategy. Approximately 12 escort vessels and one ASW carrier, in addition to 16 nuclear-powered attack submarines (SSNs) and 11 diesel-powered attack submarines (SSKs), would participate in the forward deployed Anti-submarine Warfare Striking Force Atlantic. Other ASW forces, including Sea Harrier, Sea King, and Lynx aircraft, would be utilized as needed.

Britain's emphasis on the surface escort mission declined greatly following John Nott's 1981 Defence Review; however, the Falklands conflict reopened the debate about the fleet's proper role and size. Currently, the RN has 52 frigates and destroyers, including those in retrofit.²³ Although perhaps a dozen surface escort ships would be devoted solely to the ASW Striking Force Atlantic, others would patrol such critical areas as the southwest approaches and the English Channel. Additional frigates are designated for the Royal Fleet Auxiliary at Argus. In total, however, perhaps 30 frigates and destroyers would keep critical sea lanes open.

The Royal Navy and Marines also provide protection for and deployment of the joint U.K./Dutch amphibious force to reinforce NATO's northern flank, the Baltic Approaches, or the Atlantic Islands.²⁴ Major equipment assets that participate directly in this mission include two amphibious assault ships (or landing platform docks—LPDs), about seven escort frigates, and one ASW carrier.

²⁰Additional EH-101 helicopters may be necessary with the formation of a joint RAF-Army brigade.

²¹Polaris SLBMs were upgraded with Chevaline in the early 1980s.

²²Submarines will enter service at the rate of one per year.

²³Excluding retrofit, the total was about 45 in 1989.

²⁴The amphibious force would in all likelihood be deployed to Norway.

Finally, the Royal Navy performs several homeland missions, including mine counter-measures (MCM) defensive mining,²⁵ search and rescue, and patrol missions. The RN currently maintains about 42 MCM vessels and 36 patrol vessels,²⁶ and it operates about a dozen other support ships.

Equipment

Royal Navy and Marines requirements for major vessels and aircraft over the next 15 years are considerable. Table 3 lists major Royal Navy and Royal Marine combatants and Fleet Air Arm assets and estimates retirement dates, replacement equipment, and replacement equipment costs.

Submarines

Most Royal Navy submarines are scheduled to be replaced before 2005. Much of the expense for replacements is due to the introduction of Trident SSBNs; however, considerable expenditure will result as SSN and SSK fleets are modernized. Figure 3 illustrates the projected future composition of Royal Navy attack submarines.

Trafalgar and Upholder class submarines will continue to replace older attack submarines.²⁷ To maintain the current SSN force, the MoD should order three SSNs every five years.²⁸ The Thatcher government has essentially maintained this rate, ordering five Trafalgar class SSNs since 1979.

However, the MoD has explicitly expressed a desire to increase the ratio of nuclear to diesel attack submarines.²⁹ A slightly higher SSN procurement rate is reflected in Fig. 3, and as Table 3 indicates, the RN must order an additional 12 Trafalgar or SSN-90 vessels over the next 15 years to maintain current force levels.³⁰

Upholder class SSKs will probably continue to replace aging Oberon class SSKs. To maintain aggregate attack submarine levels, albeit with a higher ratio of SSNs to SSKs, the RN should order an additional five SSKs in the next 17 years.³¹ Table 3 assumes this lower procurement rate for SSKs. In short, under the assumptions outlined, the RN must add 17 attack submarines, in addition to the five currently on order, to maintain fleet size.

²⁵Of course, MCMs are not limited to home waters, as the RN presence in the Persian Gulf demonstrates.

²⁶Including retrofits.

²⁷SSN and SSK retirement is assumed to occur at 25 years. Thus, in (approximately) 1993, Trafalgar SSNs should have replaced the two remaining Valiant class SSNs. By 1998, Trafalgar should have replaced the three Churchill class SSNs; and by 2005, Trafalgar or a suitable follow-on (SSN-90) should have replaced the six Swiftsure SSNs.

²⁸This is calculated by the size of the fleet (15) divided by the average retirement age (25). This replacement rate is valid in the long run, although in the short run, this may not maintain fleet size if a large percentage of vessels are soon nearing retirement age. Lead production time for SSNs is about six years. See House of Commons Defence Committee, 1986, p. 114.

²⁹Statement on the Defence Estimates 1987, Vol. I, pp. 25-26.

³⁰As noted in Table 3, this does not include the four Trafalgar SSNs in service (by the beginning of 1989) or the one on order.

³¹This is in addition to the four Upholder class SSKs currently on order.

Table 3
MAJOR ROYAL NAVY EQUIPMENT
(Millions of £1987)

Current Equipment	No. ^a	Average Age	Replacement Equipment	No.	IOC ^b	Unit Production Cost	Total Cost ^c	Costs, 1988-2005
Fleet Air Arm								
Sea Harrier FRS.1	3/30	10	None ^d	NA ^e	NA	NA	0	0
Sea King HAS.5	7/70	5 ^f	EH-101/other	7/70	1998	4.9 ^g	345	345
Lynx HAS.2/3	3/30	17	EH-101	3/30	1991 ^h	4.9	145	110
Sea King AEW.2	1/10	5	EH-101/other	1/10	1998	4.9	50	50
Sea King HC.4	3/30	5	EH-101/other	3/30	1998	4.9	145	145
Sea King Mk.4/5	2/20	5	EH-101/other	2/20	1998	4.9	100	100
Miscellaneous support	2/20 ⁱ	NA	NA	2/20	NA	NA	100	100
Sub-total								£850
Submarines								
Polaris SSBNs	4	19	Trident	4	1994	2315	9100 ^j	4500 ^k
Trafalgar, Swiftsure, Valiant, Churchill, class SSNs	16 ^l	11	SSN 20	10	1998 ^m	230	2300	2300
Oberon class SSKs	11	17	Upholder	9 ⁿ	1988	124	1118	870
Surface Ships								
ASW carriers	3	4	None	NA	NA	NA	0	0
Fearless, Intrepid assault ships	2	22	Undesignated ^p	2	1995	100	200	200
Type 42, 82 class destroyers	13 ^q	8	Undesignated ^r	12	1997	150 ^s	1800	1800
Type 12, 21, 22 class frigates	39 ^t	14	Type 23	20 ^u	1989	96	1922	1730
			Type 22	3 ^v	1989	150	450	150
			ASW frigate	10	2002	150 ^w	1500	1500
Support ships	NA	NA	Auxiliary oilers	6	1993	115 ^x	690	690
			Aviation support	1-2	1993	68	135	135
			Miscellaneous support, patrol	20	NA	10	200	200
MCMVs	42 ^y	6	MCMVs	16	1991	30	480	400
Sub-total								£14,820
TOTAL COSTS								£15,670

SOURCES: Author's estimates; Beaver, 1982; and Statements on the Defence Estimates, 1971-1989, unless otherwise indicated.

^aNumber of aircraft denotes squadrons/aircraft.

^bInitial operational capability, or in-service date.

^cSome numbers are rounded.

^dA late-1990s replacement is possible. Defense and Economy World Report, 1987. No replacement is assumed until after 2005.

^eNA denotes not available or not applicable.

^fAir Pictorial, 1988b.

^gSee Table 2 for cost data.

^hAviation Advisory Service, 1988.

ⁱIncluding two training squadrons and other miscellaneous support.

^jRecent information shows continued decreases in Trident costs of about £100 million. Aviation Advisory Service, 1989a.

^kAuthor's estimate of remaining production costs. Slightly over one-third of Trident spending had been committed by mid-1988, although only about £1.5 billion had been disbursed. House of Commons, 1987, and National Audit Office, 1987. Estimated total cost fell by about 8 percent from 1985 to 1988, although the U.S.-U.K. exchange rate improved by about 15 percent.

^lOne or two Swiftsure, as well as the four Trafalgar SSNs currently in service, will remain in operation to 2005; thus, the additional three Trafalgar and 10 SSN-20 boats cited here will increase the total number of SSNs in service as described in the text.

^mAssumes a lag in deliveries of SSNs after Trafalgar deliveries in order to accommodate Trident production.

ⁿFour are currently on order. One was scheduled for delivery in 1988-89. As indicated in the text, the total number of SSKs will probably decline between 1988 and 2005.

^pThese will probably be replaced at a cost of £200 million.

^qSome of these will remain in service to 2005.

^rThe U.K. recently withdrew from NATO Frigate (NFR-90) participation; however, a replacement destroyer is expected. Britain apparently withdrew since the NFR-90s projected production schedule did not meet its requirements. De Briganti and Hitchens, 1989.

^sBased on estimated costs of NFR-90/equivalent ship. Riddell, 1988; and Hooten, 1988.

^tIncludes 13 Type 22, six Type 21, 18 Leander, one Rothesay class, and one navigation training ship. The latter is engaged primarily in training exercises.

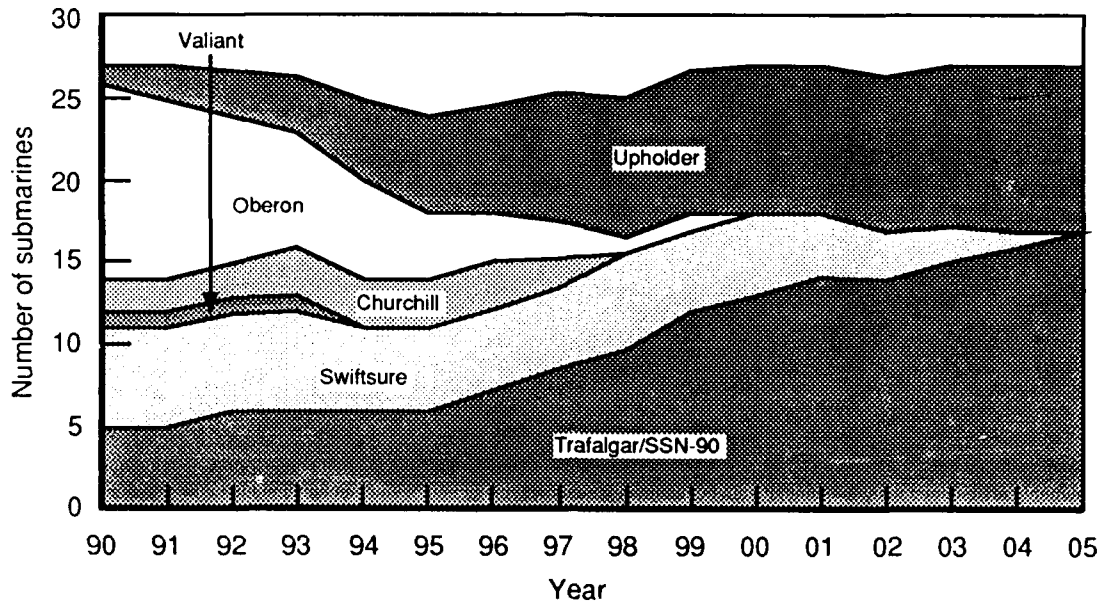
^uBased on Dunn, 1987. The MoD later denied it planned an order of this size; however, approximately 33 new frigates, shown here as three Type 22, 20 Type 23, and ten ASW frigates are required to maintain current force structure. Four Type 23s are on order.

^vOne on order currently.

^wAssumed to equal NFR-90/AAW destroyer cost.

^xJane's Defence Weekly, 1988.

^yTon class MCMVs are likely to be replaced before 2005. Other MCMVs are fairly new and few will be replaced before 2005.



NOTE: Figure 3 is notional. I have tried to maintain a top-line of approximately 27 SSNs and SSKs through 2005. Vessels are retired *near* but not exactly at 25 years to maintain this constant top-line count except in the mid to late 1990s when Trident production will crowd out SSN production. Figure 3 considers SSNs and SSKs currently on order in determining top-line numbers for the next three to four years.

Fig. 3—Royal Navy attack submarine assets

Surface Combatants

Requirements for Royal Navy major surface combatants are also considerable. Figure 4 illustrates the projected future composition of major Royal Navy surface combatants.

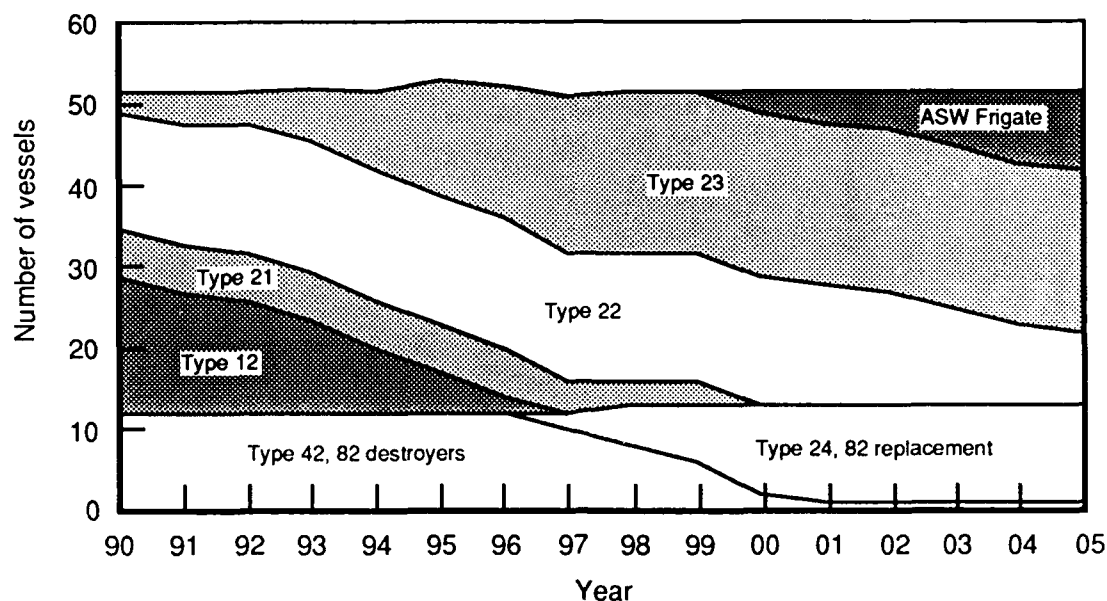
John Nott's 1981 *Defense Review* stated a goal of maintaining "about 50" frigates and destroyers, and this goal has been repeated.³² Approximately three new frigates are needed each year to maintain the current fleet size.³³

Type 23 and Type 22 ships will continue to replace aging Type 12 and 21 frigates in the ASW role. In the longer term, an undesignated ship should replace Type 42 class destroyers in the anti-air role.³⁴

³²Statement on the Defence Estimate 1989, Vol. I, p. 24.

³³This assumes no retrofits on newer ships and a useful lifetime of 18 years. Although the RN's stated policy is to minimize the number of mid-life retrofits, a large number of retrofits were underway in 1989 (16 percent of the frigate and destroyer fleet was undergoing retrofit or on stand-by for retrofit; 22, 17, and 7 percent of the fleet were undergoing retrofit in 1970, 1975, and 1983, respectively). Thus, some ships will probably undergo retrofit, and others will not, and the average retirement age will fall between 18 and 25 years. If the average retirement age is 21.5 years, as a rule of thumb, about 2.5 ships should be ordered each year to maintain the current fleet.

³⁴Britain recently withdrew from NATO's NFR-90 program. De Briganti and Hitchens, 1989.



NOTE: Alternative ship designations limit confusion about British frigates. Type 23 represents Duke or Norfolk class, Type 42 Birmingham, Type 12 Leander, Type 22 Broadsworth, and Type 21 Amazon. Bristol class (Type 82) vessels are included in Type 42 total.

Fig.4—Royal Navy major surface combatants

In sum, 45 of the existing 52 frigates and destroyers must be replaced before 2005 to maintain current strength.³⁵ However, the MoD has not maintained this rate, ordering a total of eight Type 22 and four Type 23 frigates since 1979, an average of about 1.5 per year.³⁶ Seven Type 22s have been delivered; no Type 23s have been delivered. At this acquisition rate, the fleet will fall to about 42 in 2005, a 22 percent decrease in the inventory.

The RN has not yet determined whether it will maintain or seek replacements for its two LPDs beyond 1995. However, given the importance of the LPDs in Royal Marine operations, failure to replace them seems unlikely. The RN also seems likely to purchase two aviation support ships.³⁷

The three ASW carriers are fairly new and should not be replaced until around 2010 or 2015, assuming that their lifetime is about 35 years. The oldest ASW carrier, the *Invincible*, was constructed in 1980.

³⁵This total includes one Type 22 and four Type 23s currently on order. An additional 40 must be ordered to maintain fleet size. If we arbitrarily extend the retirement age by five years, the RN must still replace 38 (i.e., order 33 more) frigates and destroyers by 2005.

³⁶Secretary of State for Defence George Younger announced plans for an order of "up to four" additional Type 23 frigates. Curtis, 1987, p. 2; House of Commons Defence Committee, 1986, p. 13. An additional 16 may be ordered. See Dunn, 1987, p. 413. However, the MoD recently stated that it does not intend to order the necessary three per year. Aviation Advisory Service, 1987.

³⁷These will probably replace the *Hermes*.

Modernization of MCMV assets should continue, although there are conflicting reports about future MCM force size.³⁸ Most new MCMV assets will replace the Ton class.

Fleet Air Arm Assets

The Sea Harrier will also probably be replaced as it nears the 20 year average age mark, although the MoD has not announced a replacement. Given the age distribution of Sea Harriers, some may be replaced before 2005.³⁹

The RN/M currently operates 16 active helicopter squadrons.⁴⁰ EH-101 squadrons will replace Wasp,⁴¹ Lynx, Wessex, and some Sea King units in the near term. In the long term, EH-101 or a similar type of aircraft will replace remaining Sea King and Wessex aircraft.

TOTAL REQUIREMENTS AND THE EFFECTS OF EQUIPMENT COST GROWTH

Table 4 illustrates the total production costs of modernizing major equipment outlined earlier in this section. Royal Navy equipment accounts for more than 40 percent of total modernization cost.

The total production costs of equipment modernization is about £38 billion. However, as noted previously, these cost estimates are based upon current MoD or other source estimates, undoubtedly understating the financial requirements since eventual production costs, particularly for systems that have not yet reached the production stage, are likely to increase. In short, cost growth for many of the systems outlined above may be substantial, as the following examples illustrate.

Table 4
MODERNIZATION COSTS OF MAJOR EQUIPMENT
(millions of £1987)

Equipment	Costs
Army equipment	8,485
RAF air defense equipment	7770
RAF strike and attack equipment	4120
RAF helicopter, transport equipment	1985
Royal Navy submarines	8015
Royal Navy surface ships	6805
Royal Navy Fleet Air Arm assets	850
Total costs	£38,030

³⁸See Wettern, 1987, p. 368. A 1980 plan called for a 15 year purchase of as many as 60 MCMVs.

³⁹*Defense and Economy World Report*, 1987, estimates a late 1990s Sea Harrier replacement. This analysis assumes no replacement.

⁴⁰This does not include training units.

⁴¹Most Wasp squadrons have been retired.

The Tornado aircraft currently operational in the British, German, and Italian air forces has experienced considerable production cost growth since 1970. Official Tornado production cost estimates over this lengthy time period are not readily available, and I have collected historical cost data from several sources, primarily trade journals, in Fig. 5. Tornado production costs *in real terms* have increased at an average annual rate of about 5 percent since 1970.

Studies in Britain also point toward the likelihood of major system production cost growth. Several sources indicate major equipment production cost growth of 7 to 8 percent per year.⁴² In particular, a House of Commons report estimated production cost growth on several major weapons systems of 29 percent over five years, or an annual rate of just over 5 percent.⁴³ The report is particularly noteworthy since it estimated that perhaps one-half of the U.K. equipment budget eventually is consumed by unexpected cost growth.⁴⁴

Previous work at RAND also demonstrates that production cost growth is likely in major systems. For example, a study of 32 systems in the 1970s demonstrated between 5 and 6 percent annual cost growth.⁴⁵ Earlier studies have recorded similar experiences.⁴⁶

The eventual production costs of major equipment will almost certainly exceed current estimates, and this study uses a range of feasible production cost growth, 0 to 8 percent, in order to estimate future costs. Table 5 summarizes total costs of major replacement equipment for the Army, Royal Air Force, and Royal Navy and Marines under three cost growth scenarios.⁴⁷ (Appendix A lists the effects of unexpected cost growth on individual Army, RAF, and Royal Navy and Marine equipment.)

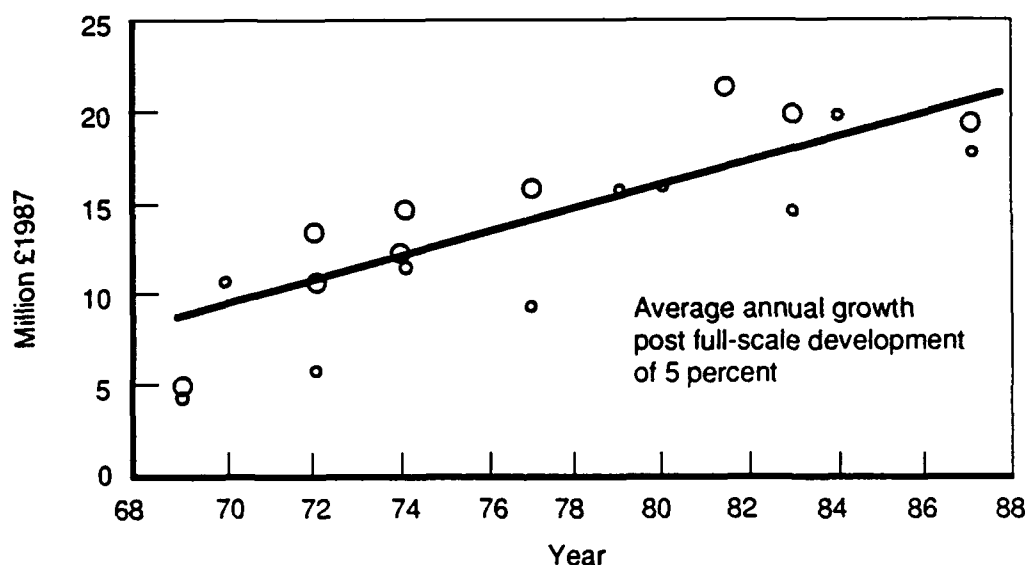


Fig. 5—Tornado production costs

⁴²Greenwood, 1985; Pugh and Kirkpatrick, 1987. Cost growth for ships is somewhat less. See Pugh, 1986.

⁴³*Jane's Defence Weekly*, 1988d.

⁴⁴This is truly staggering since it represents, in essence, 100 percent average system (development and production) cost growth.

⁴⁵Dews et al., 1979, p. 39. This figure represents cost growth beyond full-scale development approval.

⁴⁶Perry, 1971. This study of 24 programs in the 1960s showed an average 44 percent increase in costs.

⁴⁷These aggregate cost growth estimates are in the 20 to 50 percent range, as found in previous work at RAND.

Table 5
EFFECTS OF COST GROWTH: ALL MAJOR EQUIPMENT*
(Millions of £1987)

Equipment	0% Growth	5% Growth	8% Growth
RAF air defense equipment	7770	10,570	12,835
RAF strike and attack equipment	4120	5265	6160
RAF helicopter, transport equipment	1985	2530	2930
Army equipment	8485	9780	10,715
Royal Navy submarines	8015	10,085	11,595
Royal Navy surface ships	6805	9020	10,850
Royal Navy Fleet Air Arm assets	850	1195	1455
Total costs	£38,030	48,445	56,545

*Some numbers are rounded.

In summary, production modernization costs for U.K. armed forces, based on current modernization plans, are estimated at about £38 billion. However, this does not include unexpected cost growth, which previous studies indicate is typical. Annual cost growth of 5 and 8 percent leads to much higher cost estimates of £48 and £57 billion, respectively. More than 40 percent of these totals result from Royal Navy modernization requirements.

III. FORECASTING U.K. DEFENSE SPENDING

British force modernization in the next 15 years will require substantial financial resources. Determining available MoD resources requires forecasting aggregate defense budget growth.

This section forecasts a range of U.K. defense spending to 2005.¹ No major change is assumed in the threat perception (as British planners have in the absence of large Warsaw Pact force reductions or conventional arms control agreements in Europe). First the section analyzes defense budget share of gross domestic product, constant defense spending over time, and the defense budget's share of total government expenditures, to forecast a range of future defense spending levels. Second, demographic and other budgetary and economic data are analyzed to forecast likely growth in other areas of the national budget that compete with the MoD for funds. This may provide some insight into possible "crowding out" of the defense share of the national budget.²

HISTORICAL MODELS

Defense's Share of GDP

Nations may typically maintain a roughly constant defense spending share of gross national or gross domestic product (GNP or GDP).³ For example, many NATO countries have maintained a roughly constant defense budget share of GDP since the early 1970s.⁴ Thus, defense spending is a function of GDP.

The U.K. defense spending's share of GDP has fallen steadily since 1955, from a high of just under 8 percent in 1955 to current levels of about 4.2 percent.⁵ It is projected to fall further in the next three years to slightly less than 4 percent.⁶

However, a fairly constant average share of GDP seems to have been devoted to defense in the 1970s and 1980s.⁷ The average share of GDP devoted to defense between 1970 and 1980 was 4.0 percent, while the average in the 1980s was 4.5 percent. The 1970-1990 average is 4.2 percent.

Long-term macroeconomic growth (hence defense budget expenditure growth) may be forecast primarily using historical or other data in macroeconomic models. Historical average annual GDP growth rates range between 2 and 2.5 percent. The growth rate in the

¹See Sandler and Murdoch, 1986; and Don, 1986, for more detailed budget forecasting methodology.

²This is intended to provide general rather than specific guidance.

³This section uses GDP data.

⁴This includes the FRG (about 3.3 percent between 1970 and about 1985), France (about 3.8 percent since 1970), Canada (about 2.2 percent since 1973), the Netherlands (about 3.1 percent since 1970), and Denmark (about 2.3 percent since 1972). Many of these budget shares have fallen in the last several years.

⁵These figures are based on U.S. Department of Defense and International Monetary Fund statistics and may not correspond directly with British sources.

⁶The lowest share was recorded in 1979 at 3.5 percent; the Thatcher buildup reached a high of 5.0 percent in 1984, according to U.S. Department of Defense and International Monetary Fund statistics. British sources show a high of 5.4 percent in 1984 and may reflect additional defense expenditures excluded from U.S. estimates.

⁷This is notable because spending as a share of GDP had fallen in almost every year until this plateau was reached.

1980s was 2.3 percent. Long-term economic growth based on changes in capital, labor, and technology is estimated at 1.7 percent per year.

About 2 percent⁸ represents an optimistic estimate of macroeconomic and defense budget growth rates from 1990 to 2005; 2 percent annual growth results in average defense expenditures of £21.4 billion and an aggregate defense budget of £343 billion from 1990 to 2005 (expressed in £1987).⁹ However, an average annual defense budget growth of 2 percent, particularly in the next several years, seems unlikely considering the recent decline in defense spending share of GDP.

Defense Spending in Real Terms

Some nations maintain roughly level defense spending in constant currency. British defense spending expressed in £1987 ranged from a low in 1971 of about £11.5 billion to a recent high in 1985 of slightly under £20 billion. Between 1955 and 1979, spending fell in real terms at the rate of 1 percent per year, but remained within a fairly narrow band, averaging £13.4 billion.¹⁰

Accordingly, a "natural" level of spending may fall between £12.5 and £14.0 billion¹¹ and suggests that future budgets might return to this level.¹² This seems unlikely, however, unless a major review of U.K. commitments occurs. For example, about three-fourths of the U.K. defense budget is devoted to operations, including personnel, maintenance, minor procurement items, and other overhead costs. The remainder is devoted to purchases of new equipment. A reduction to a level of £12.5 to £14 billion would force either a *drastic* reduction in forces and missions, possibly including the retirement of fairly modern equipment, or the termination of new equipment purchases. A less precipitous decline of 1 percent per year, however, similar to that from 1955 to 1979 seems plausible. In this scenario, aggregate spending from 1990 to 2005 totals £320 and average defense spending equals £20.0 billion (in £1987).

Defense Share of General Government Expenditures

The defense budget's historical share of U.K. general government¹³ expenditures demonstrates past defense and nondefense spending priorities and may also provide insight into future trends in defense expenditure. For example, recent increases in nondefense programs—such as health, social security, and education—might indicate that it will become in-

⁸The 2 percent figure was chosen somewhat arbitrarily. It is higher than GDP growth since 1965, but lower than that from 1955 to 1964.

⁹Ministry of the Treasury defense budget projections to 1991 are used and 2 percent annual growth projected beginning in 1992. The Ministry of the Treasury projects 1990 and 1991 defense spending (in £1987) of £18.5 and £18.8 billion, respectively; these are optimistically based on expected annual inflation rates of 3.5 and 3 percent, respectively. Inflation rates similar to current ones in Britain will result in considerably lower spending in real terms.

¹⁰The standard deviation is 936, indicating only modest annual changes. Much of the decrease from 1955 to the early 1970s resulted from the termination of overseas commitments and a steady decrease in Royal Navy assets.

¹¹This range captures about 70 percent of all data points between 1955 and 1979.

¹²A similar argument has been advanced regarding the U.S. defense budget. See Lewis, 1987.

¹³General government expenditures include national and local expenditures. Local expenditures have historically accounted for about one-third of general government expenditures.

creasingly more difficult for defense expenditure to maintain a future constant share of general government expenditures.

The British defense expenditure share of general government spending has fallen from nearly 15 percent in 1967 to about 13 percent in 1989, while some other program shares have increased slightly. Social security and housing expenditures¹⁴ have increased from 27 to 31 percent of all expenditures. Other categories have remained fairly constant. In short, defense spending's share of general government expenditures indicates a decreasing emphasis on defense expenditures.

This relative decrease in defense spending has occurred as general government expenditure share of GDP has decreased. The general expenditure share peaked in 1975 at just under 49 percent,¹⁵ while the low point (not surprisingly) occurred in 1955 at 33 percent. The general government's share of GDP increased in the first three years of the Thatcher government; much of this appears to have resulted from high social security payments, including unemployment compensation, during the early 1980s recession. Since 1982, however, the expenditure share of GDP has decreased from 46 percent to about 39 percent.¹⁶

A continued reduction in central government expenditures as a share of GDP indicate that programs *in general* will not be able to increase as rapidly as the economy expands. Of course, individual programs, including defense, may increase as a share of total expenditures, but only if other program shares *decrease*. Thus, current government policy of further decreasing total government spending limits opportunities for defense budget growth. A Labour government, while less committed to reducing the size of central government, would almost certainly favor nondefense over defense program expansion.¹⁷

In sum, defense spending has fallen relative to other spending programs and now averages about 13 percent of all government spending. The likelihood of a reversal in this trend is remote.

FUTURE GROWTH IN CENTRAL GOVERNMENT EXPENDITURE CATEGORIES

Future growth in many general government expenditure categories, of course, results from political decisions within participating ministries and the Houses of Parliament and is thus difficult to forecast.¹⁸ However, certain expenditures are related to demographic and economic factors and may be estimated with a reasonable degree of confidence. For example, the total number of future health care recipients and the expected average costs of future

¹⁴This seemingly arbitrary grouping is used because housing has been included in the social security account since 1984.

¹⁵High levels in 1975 and 1976 probably resulted from a combination of a recession and increased social spending on unemployment benefits.

¹⁶This includes expected receipts of £6 billion in 1989 from privatization of state-owned businesses. HM Treasury, 1988.

¹⁷It is questionable, in fact, whether any party would advocate a substantial increase in defense spending in the short to medium term. A recent poll shows more Britons favoring a cut in defense spending than an increase (Fairhall, 1987); 27 percent favor a decrease in spending, 17 percent favor an increase, and the remainder are undecided or favor no change in spending. This poll was conducted before many Soviet arms control proposals.

¹⁸Most expenditure categories (such as trade and industry, environment, agriculture, fisheries, food, or transportation) are inherently unpredictable. However, these categories constitute a small part of general government expenditures. Larger expenditure categories, such as health, education, and social security, may be more easily predicted.

health care provide a useful estimate of future health care expenditures *if available benefits remain fairly constant over time*.¹⁹

Education, social security, and health expenditures account for nearly two-thirds of all general government spending, are related to demographic changes, and can be easily forecast. Accordingly, future expenditures in these categories may provide some insight into the possible crowding out of defense spending.

Education

The Department of Education and Science accounts for roughly 13 percent of all British general government spending. (Education accounts for most of this expenditure.) Forecasting future education and science spending requires fairly detailed demographic data but also specific assumptions about the number of students in private schools, attendance rates, average costs per student, and expected increases in teachers' salaries. Assumptions used in this section to forecast future Education and Science Department spending are found in App. B.

If participation rates, the number of students in private schools, and attendance rates at universities and other higher institutions remain constant through 2005,²⁰ Education and Science forecasts become simple using available demographic data. Education and Science Department expenditure forecasts for 1991, 1996, 2000, and 2005 are listed in Table 6, which contains two expenditure forecast variants: The first assumes that teacher salaries do not increase in real terms, and the second estimates real salary increases at 1.5 percent per year.²¹ Both are based on available data on expected numbers of students.

Table 6
FORECAST OF U.K. EDUCATION AND SCIENCE EXPENDITURES
(Millions of £1987)

	1991	1996	2000	2005
No salary increases (low variant)	6,800	18,630	18,000	17,365
1.5%/year salary increases (high variant)	17,100	19,500	19,200	19,000
Average yearly increase (high variant), percent	-.1	+2.7	-.3	-.2

¹⁹A more extensive study might examine the relationship between health, education, and social security expenditures and population changes among specific demographic groups. This would require an exhaustive review of benefits and is beyond the scope of this analysis.

²⁰Granted, this is a simplifying assumption, but it is necessary to keep this section to a minimum. For further details, see Levitt and Joyce, 1984.

²¹Teacher shortages in Britain may result in higher salary increases. Recently, bonuses have been offered to entering science and math students in hopes that they will choose a teaching career. Bonuses may soon be added to increase the number of modern language teachers. Garner, 1989.

Under the assumptions noted above, education expenditures will crest in the mid-1990s and remain flat to slightly down through 2005. Education may grow more slowly than the general economy and account for a smaller share of the general budget than it now does. Closer examination of demographic data explains this fairly flat expenditure forecast. Although the number of under five, other primary, and secondary students increases slightly, the number of university and Advanced Further Education students falls.

In short, education and science expenditures will probably not contribute to crowding out defense spending through the year 2005 unless benefits increase greatly, participation rates soar, or teacher salaries increase greatly. The education budget may fall slightly below its current 13 percent share of general government expenditures.

Social Security

The U.K. social security system closely resembles that in the United States and includes contributory and noncontributory benefits.²² Payments to pensioners account for 75 percent of all contributory benefits. Noncontributory benefits include unemployment compensation, single family support, and housing benefit schemes. Administrative costs are roughly 4 percent of all social security expenditures. The British social security system and expected trends are explained in App. B.

Demographic data on the number of pensioners provide insight into future contributory expenditures, and the number of children into noncontributory expenditures. (Administrative costs are assumed to be a constant percentage of expenditures.) Based on these data, contributory benefits should increase only slightly in the coming two decades, as the number of pensioners increases. The modest increase in the total number of pensioners should lead to a yearly increase of less than one-half of 1 percent in contributory benefits between 1990 and 2005.²³

Noncontributory benefits may also remain flat, as the number of children remains stable.²⁴ Closer examination of demographic data indicates an average annual increase in the number of children of one-half of 1 percent between 1990 and 2005. Thus, noncontributory benefits probably won't increase at a rate much faster than growth in GDP. Of course, a continuation of current trends, such as the steady increase in the number of single parent families, might lead to greater increases in noncontributory benefits.

²²Contributions to the social security account also parallel the U.S. system. Thus, the government may increase social security tax contributions if outlays are expected to increase. In this case, increases in social security outlays would probably not crowd out defense or other expenditures unless there were maximum aggregate national spending levels. For more general information on social security expenditures, see *The Government's Expenditure Plans 1989-90 to 1991-92*, 1989; *Social Security Statistics*, 1987; and Jackson and Terry, 1987.

²³This may be a somewhat optimistic assessment since benefits may not increase as real earnings increase. Instead, social security expenditures are likely to follow increases in real earnings, which are assumed to grow at a rate comparable to GDP growth of 2 percent per year. Under this assumption, contributory benefit expenditures would increase at the worrisome but not alarming rate of 3 percent per year.

²⁴Noncontributory benefits are also related to unemployment rate. The average unemployment rate should remain at current levels through 2005.

Health and Personal Social Services

Health and Personal Social Services account for 15 percent of British general government expenditures. This share will probably grow modestly through 2005 as health care costs and the number of elderly in the population increase. Health care costs have recently increased in real terms at an average annual rate of 2.5 percent. The number of aged in the population will increase less than this; however, their large share of total health care costs results in a disproportionate expenditure increase.²⁵ Details on these forecasts are found in App. B.

Health and Social Service costs will probably increase at a rate near 3 percent per year, while GDP growth rates are expected to be nearer 2 percent. Health care costs may occupy between 18 and 19 percent of total general government expenditure in 2005, although this modest increase would probably not contribute greatly to crowding out defense expenditures.²⁶

CONCLUSIONS

Nondefense expenditure categories are unlikely to force reductions in long-term defense spending; however, historical defense budget expenditure data suggest a potential long-term decline similar to what occurred from 1955 to 1979. This low resource scenario should produce an approximate 1 percent per year decline in real defense expenditures. (All scenarios include Ministry of the Treasury budget projections to 1991 and estimated defense budget growth beginning in 1992.) In a high resource scenario, defense budget share of GDP should remain constant. In this scenario, defense expenditure increases at an annual rate of 2 percent. In a middle expenditure scenario, the defense budget should increase at an average annual rate of 1 percent. Each of these scenarios bases future resources on past expenditure patterns and thus does not include reductions in resources resulting from conventional arms control agreements.

²⁵For example, the Department of Health and Social Services (DHSS) estimates that it costs nine times as much to care for those 75 and older compared with rates for the working population (ages 15-64). Cited in Levitt and Joyce, 1984.

²⁶Efforts to privatize some health care and personal social services may further mitigate increases.

IV. THE BRITISH DEFENSE BUDGET MODEL

This section develops a model for British defense spending using historical data.¹ This model projects available funding levels for specific budget categories, including the production of major equipment items as described in Sec. II. Thus, available resources and requirements for major equipment production can be easily compared.

The budget model developed in this section is a residual model. It estimates funding available for the production of major equipment by subtracting estimated future expenditures for all other budget categories (personnel, operations, and other nonmajor equipment expenditures) from total projected resources. Future expenditures for all other categories are based on estimated personnel requirements, personnel costs, and historical relationships between various expenditure categories. The residual represents available funding for the production of major equipment items.

In constructing the model, investment expenditures, major equipment expenditures in particular, are assumed to be the most discretionary defense budget categories. In other words, if aggregate defense spending changes, operations and personnel expenditures will change relatively less than investment expenditures. For example, a decrease in the defense budget will lead to modest reductions in operations and personnel expenditures and to larger reductions in investment expenditures. The opposite holds for increases in the defense budget.

A cursory examination of historical expenditure data appears to confirm these assumptions. For example, ordinary least squares regressions demonstrate little relationship between aggregate defense and either operations or personnel expenditures; however, there is a significant positive correlation between aggregate defense and major equipment production and investment expenditures.²

POTENTIAL PITFALLS IN LONG-TERM BUDGET FORECASTING

Long-term budget forecasting is a difficult task and must be undertaken with great care. In particular, the quality of the data used to develop the model is important. Most budget models, including this one, are developed from historical data and are subject to several caveats. First, historical data may not necessarily represent future expenditure patterns. For example, because of technical innovation or other developments, future maintenance or other expenditures may not correspond to observed historical expenditure patterns. As a result, projected expenditures may not correspond to actual future expenditures. The likelihood of this appears small, however, and its effects are minimized because expenditure patterns are observed over a long period.

¹Data from annual *Supply Estimates* rather than the *Statement on the Defence Estimates* are used for various reasons, including data availability and required level of budgetary detail.

²This series of regressions sets the independent variable (aggregate defense expenditures) against three dependent variables (personnel, operations, and investment). Forcing the β coefficients to sum to 1 results in β values for investment, personnel, and operations of .78, .05, and .17, respectively. In other words, investment expenditure falls (rises) .78 percent for each 1 percent fall (rise) in aggregate defense expenditures.

Second, changes in the content of expenditure categories, observed historically or expected in the future, may lead to inaccurate results. For example, an expenditure category that describes land equipment may from time to time include maintenance or unexplained expenditures. Although these occurrences are rare, inconsistent category content can complicate long-term forecasts. The dangers from changes in expenditure category content are minimized by aggregating expenditure categories. Conservative assumptions are made about category content. This latter measure may understate eventual requirements.³

Third, developing a model from only a few years of historical data may mask actual expenditure patterns and relationships among expenditures. For example, a model developed from recent expenditures in Britain would erroneously suggest that the aircraft production share of aircraft procurement has been historically low because of the lull after Tornado deliveries. These effects are minimized because 19 years of expenditures were examined.

Finally, two other potential pitfalls in budget forecasting deserve some attention. First, more accurate results are likely if an interactive rather than a static budget model is developed. In particular, development and maintenance expenditures should be tied to procurement or other factors. This model is interactive and that should minimize potential pitfalls. Second, if possible, the model should develop highly specific relationships between expenditure categories and other available data and that should provide more accurate forecasts. For example, a highly specific model might forecast RN maintenance expenditures by observing the historical relationship among expenditures, the number of major and minor combatants, the vintage of ships, an index describing ship complexity, and other factors. Unfortunately, this level of effort is beyond the scope of this report. However, this model is sufficiently complex to accurately forecast expenditures in this and other categories.

DEFENSE EXPENDITURE CATEGORIES AND MODEL STRUCTURE

The British defense budget can be broken down into three major categories: procurement, personnel, and operations.⁴ Historical data demonstrate a fairly constant division of monies among these three categories. (Appendix C contains detailed statistical information on British defense spending since 1971.) Personnel and procurement have together maintained roughly 80 percent of total expenditures, and operations have made up the remaining share. A notable trend is the relative increase in procurement expenditures and the relative decrease in personnel costs.⁵ The privatization of some MoD facilities⁶ and the subsequent transfer of personnel to the private sector explain this trend in part; however, an increasing defense budget, a more conscious resource allocation policy, and greater use of contractors appear to be the main reasons.

³Refer to App. D for more information.

⁴This breakdown corresponds to that found in the annual *Statement on the Defence Estimates*. The annual *Supply Estimates* uses a somewhat different breakdown. The 1989-90 *Supply Estimates*, for example, lists defense expenditure by parliamentary votes on active personnel, retired personnel, procurement, accommodation services, ship refitting and repair, and sale of government shares in the Royal Ordnance Factories. This analysis relied heavily on the *Supply Estimates*. All data cited in this section are net expenditures.

⁵This was particularly noticeable between 1980 and 1988.

⁶Including BAe, Rolls Royce, the Royal Dockyards, and the Royal Ordnance Factories. These privatizations apparently did not appreciably alter the share of equipment expenditure since payments to these organizations have always been included in the equipment category.

Personnel expenditure categories include active duty, civilian, and retired personnel, while operations include several miscellaneous categories. Procurement expenditure includes research and development, production, and maintenance.⁷ Table 7 lists major British defense budget categories and their 1989 spending levels in £1987.⁸

Table 7
THE NET 1989 DEFENSE BUDGET^a

Expenditure Category	Millions of £1987 ^b	Share (percent)
Total	18,225	
I. Operations	3,745	20.6
II. Personnel	6,930	38.0
Retired	1,090	5.9
Active duty	4,140	22.7
Civilian	1,700	9.3
III. Procurement	7,545	41.4 ^c
A. Misc. procurement, research	1,185	6.5
B. Land systems	1,520	8.3
Development	280	1.5
Minor equipment	595	3.3
Maintenance	325	1.8
Major equipment production	330	1.8
C. Air systems	2,760	15.1
Army, RN systems	435 ^d	2.4
Development	580	3.2
Minor equipment	790	4.3
Maintenance	460	2.5
Major equipment production	495	2.7
D. Sea systems	2,085	11.4
Development	340	1.9
Minor equipment	540	3.0
Maintenance	680	3.7
Major equipment production	520	2.9
Total major equipment production	1,345	7.4

^aNet production expenditures for some major equipment items have been estimated. For example, land production includes several gross expenditure equipment categories and a figure for land production aid. (Aid signifies assistance to other countries.) In most cases, aid is assumed to be distributed evenly across all gross production categories and net expenditures are adjusted accordingly.

^bSome numbers are rounded.

^cThis number may differ with the share of procurement expenditure listed in the *Statement on the Defense Estimates* since the *Supply Estimates* includes some personnel and associated costs not found there.

^dAuthor's estimate.

⁷Unlike U.S. defense budget expenditure data, the British budget includes maintenance in procurement rather than in operations spending. Thus, comparisons of the share of procurement in aggregate defense spending across U.S. and British budgets should be made with caution (i.e., the U.K. procurement share will be inflated).

⁸This analysis converts all expenditure data to £1987 using deflators from the International Monetary Fund, *International Financial Statistics*.

Procurement expenditure in the U.K. is not broken out among service categories, but by land, air, and sea equipment. Although these correspond roughly with Army, RAF, and Royal Navy and Marine procurement expenditures, there are many differences. For example, all Royal Navy and Army air equipment is in the air procurement category. Similarly, RAF ground air defense systems are in the land procurement category. This accounting procedure requires some very minor transfers to maintain consistency with the budget model, for example, of service equipment requirements outlined in Sec. II. Appendix D details these accounting changes.

Table 7 also illustrates major equipment production expenditure's minor share of the total defense budget. In 1989, for example, only £1,345 million, or 7.4 percent of total spending, occurred on major equipment production. Operations, personnel, and other equipment purchases, including development, maintenance, and minor equipment items, account for the remainder.

OPERATIONS

The operations category contains numerous expenditures, including movements of personnel and equipment, miscellaneous stores, clothing and victualling, fuels and utilities, the maintenance and administrative costs of existing buildings, and other expenditures. Additional minor expenditures range from ship refitting to accommodation services, including land and building purchases, to third party payments for weather reporting services. Table 8 lists 1989 operations categories and expenditures.

The share of each subcategory in aggregate operations expenditures has remained fairly constant over time, although variations in world energy prices have led to some fluctuation in fuel and utilities expenditures. Uncertainty about future fuel prices complicates forecasting in this category, although British North Sea oil reserves would probably lessen any future global fuel price increases. Other subcategories appear likely to maintain their constant historical shares of operations expenditures.

Table 8
1989 NET OPERATIONS EXPENDITURES ^a
(Millions of £1987)

Movements of personnel, equipment	355
Stores	385
Clothing, victualling	130
Fuel, utilities	435
Accommodation	1,645
Other	805
Total	£3,745

^aSome numbers are rounded.

Operations share of the defense budget has averaged about 20 percent in both the 1970s and 1980s.⁹ Operations share in the 1970s was 21.6 percent—it fell slightly to a 20.5 percent share in the 1980s. Future operations share should continue to be 20.5 percent.

PERSONNEL EXPENDITURES

Personnel expenditures, including expenditure on active forces, civilian MoD, and retired personnel, have recently occupied a smaller share of total defense expenditures. From 1971 to 1989, personnel expenditures accounted for 37 percent of all British defense spending, although there has been a clear downward trend in its share of the total budget.¹⁰ This has occurred as personnel expenditures have remained fairly level or grown slightly in real terms while procurement expenditures have increased greatly.

Model Estimation of Retired Personnel Expenditures

Retired pay constitutes nondiscretionary spending in the purest sense. For example, the MoD will continue to honor its obligations to retired servicemen and women regardless of the future composition of U.K. missions and equipment assets.

Historical data indicate an increase from 213,000 to roughly 228,000 service pensioners since 1971; however, it is unclear whether this upward trend will continue. On the one hand, the number of pensioners might be expected to decrease slightly in conjunction with the decline in armed forces personnel that began in the 1950s. However, this is inconsistent with observed data; and countervailing effects, such as changes in life expectancy or changes in pension policies, have apparently accounted for the observed increases in the number of pensioners.¹¹ In a high expenditure case, increases in the number of eligible pensioners are forecast at two-thirds of 1 percent, or twice its observed annual historical rate. In this scenario, the number of pensioners increases 10.5 percent to just under 252,000 in 2005. A low expenditure scenario forecasts no increases in the number of pensioners above 1989 levels. A middle expenditure scenario forecasts increases in the number of pensioners at the historic rate of one-third of 1 percent per year, resulting in 241,000 pensioners in 2005.

Data on average increases in pension payments indicate an alarming trend. Real earnings per service pensioner have increased 45 percent, or an average annual rate of 2.0 percent since 1971. (This average annual rate represents a fitted line to pension expenditure data since 1971.) This sharp increase has led to retired pay now occupying nearly 16 percent of the personnel budget.

Two factors account for this rapid increase. First, the introduction of an all-volunteer force in 1957 probably resulted in more generous pension plans. Pension awards were further improved in the early 1970s, although the effects of these improvements until now have

⁹This excludes 1971/2, 1974/5, and 1975/6 data. It is unclear whether these data are an aberration or a collection of data errors since operating expenses for these years are estimated from sources other than the *Supply Estimates* and *Statement on the Defence Estimates*. See App. C for more information. It is conceivable that these represent higher fuel prices following the 1973 Arab oil embargo.

¹⁰The underlying reasons for this decrease are explained below.

¹¹A 20 year retirement age is standard. Thus, one would expect to have observed a decrease in the number of pensioners in the late 1970s, 20 years after personnel forces began to decline.

probably been modest.¹² Second, service salaries have increased at a rapid rate since 1979.¹³ Because pensions are based on final service salary, the pensions of those who have retired since 1979 have paralleled these salary increases.

A high expenditure scenario anticipates increases in individual pension awards at an average annual rate of 3 percent, reflecting rates of increase higher than those observed historically because of recent active force pay increases and corresponding improvements in retired pay guarantees for service personnel who entered after 1970. A low expenditure scenario forecasts average pension awards to increase at one-half the observed historical rate of 2 percent. A middle case forecasts that average retired pay will increase at its historical rate of 2 percent. Table 9 summarizes retired pay scenarios and projected expenditures.

Table 9
MODEL ESTIMATION OF RETIRED PAY
(Annual percentage increases in pensioners and
pension awards; expenditures in millions)

Scenario	Pensioners	Pension Award	Expenditures, 1990-2005
High	.67	3.0	24,015
Middle	.33	2.0	21,300
Low	0	1.0	18,965

Model Estimation of Active Force Personnel Expenditures

Active force personnel expenditures constitute about 23 percent of total defense spending. Forecasting this expenditure category precisely requires information on active force requirements, including needed skill levels, and available resources (military age personnel).¹⁴ This analysis uses a simpler approach and focuses on future personnel requirements (based on historical changes in personnel requirements) and resources (based on the number of military age persons in the population).¹⁵

Personnel requirements, based on the number of active service personnel, have decreased since 1971.¹⁶ The number of active Army personnel has fallen 8 percent; the numbers of active RAF and RN personnel have fallen 21 percent and 28 percent, respectively. However, the numbers of active force personnel have fallen only as the number of major combatants have declined. For example, active personnel *per major combat unit* (Army regiments or battalions, RAF aircraft squadrons, and Royal Navy major combatants) have re-

¹²Improvements in the early 1970s would affect pensions for pre-1970s enlistees only if the improvements were retroactive. Improvements in the 1970s will very likely be more pronounced in the early to mid 1990s.

¹³The Thatcher government has accelerated pay increases in hopes of restoring pay comparability for the armed services.

¹⁴A more detailed forecast would require much additional information, including recruitment and retention rates, average length of service, recruiting practices, and a host of other information. Data limitations necessitate a more limited approach.

¹⁵Some reports indicate an increasingly severe British problem with recruiting and retaining skilled personnel, so this model may understate wage increases.

¹⁶Actual MoD personnel levels since 1971 are assumed to represent required MoD personnel levels.

mained constant.¹⁷ This suggests that the number of personnel necessary to maintain current force structure to 2005 (as outlined in British modernization plans) will remain near current levels. Figure 6 illustrates the average annual number of service personnel¹⁸ as a share of specific force structure since 1971.

Army personnel per armored, artillery, engineering, and infantry battalion or regiment¹⁹ since 1971 demonstrates a constant ratio of about 1450 personnel. In fact, the Army has shown some modest efficiency gains. In the 1970s, this ratio averaged 1515; in the 1980s, it has decreased slightly to 1474, representing a decrease of nearly 3 percent.

The number of RAF personnel per squadron (excluding ground air defense squadrons) has increased. For example, this ratio in the 1970s appears slightly below 1480; it increased to 1620 in the 1980s, nearly 10 percent. The ratio of personnel per combat squadron (not shown in the figure) shows similar results.²⁰ It decreased to just above 3000 in the late 1970s and the early 1980s and returned recently to nearly 3800, about a 5 percent increase.

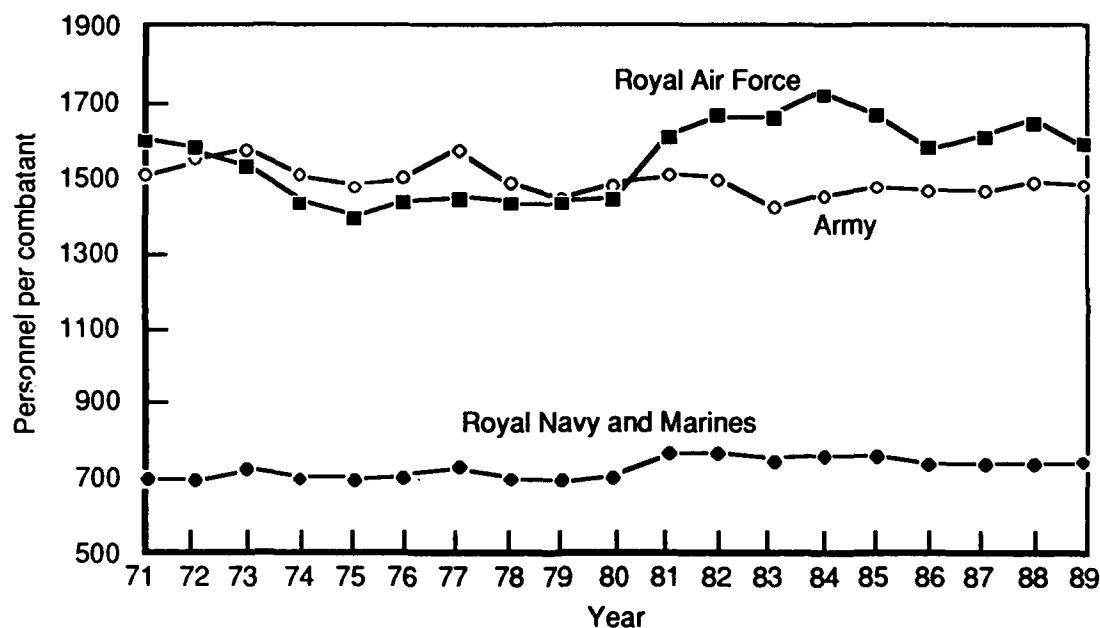


Fig. 6—Service personnel per major combatant

¹⁷There is little doubt, however, that equipment modernization has increased the effective fighting power of individual combat units.

¹⁸*Statement on the Defence Estimates, 1971-1989 and Supply Estimates, 1971-1989.* Average active personnel including those in training.

¹⁹British Army regiments and battalions are comparable in size. Thus, they can be combined to assess personnel efficiency.

²⁰This includes strike/attack, air defense, and ground support tactical aircraft squadrons.

The number of Royal Navy and Marine personnel per major combatant²¹ has increased slightly from just under 700 in 1971 to about 740 in 1989. The average 1970s ratio is 702, and the 1980s average is 745, a 6 percent increase. (The ratio of active personnel excluding the Royal Marines leads to similar results, increasing from a 1970s average of 629 to a 1980s average of 663.) In short, despite the introduction of more modern equipment, there has been no decrease in Royal Navy personnel requirements per major combatant.

In short, aggregate British active personnel requirements have fallen, although only in conjunction with decreases in major combatants. Because no further decreases in combatant force structure are planned, the number of future required personnel may remain unchanged from current levels. In fact, historical increases in Royal Air Force and Royal Navy personnel per combatant not offset by modest decreases in Army personnel per combatant may indicate slight future increases in the number of active personnel.

A high personnel expenditure scenario forecasts a gradual increase of 3 percent in future active force personnel requirements. This is unlikely, particularly considering Britain's efforts to decrease personnel requirements. A low expenditure scenario forecasts annual personnel decreases of 1 percent, roughly parallel to historical decreases in active personnel. This scenario assumes decreases in personnel requirements resulting from the introduction of more modern equipment. A middle expenditure scenario forecasts no future changes in active personnel requirements based on historical personnel per combatant ratios and Britain's commitment to maintain its current combatant structure.

Future salaries of military personnel are a function of several factors, including the unemployment rate, real wage increases in the civilian sector, and perhaps some less quantifiable measures, such as levels of patriotism. Economic analyses have also demonstrated the effects of cohort size on relative wages.²² Wages in small population cohorts will increase relative to average wages; conversely, the wages of large cohorts will decrease.

Two potential wage increases affecting military personnel are forecast to result from Britain's declining 16 to 19 year old male youth cohort.²³ The first results from the relative decrease of youth laborers in the economy as a whole.²⁴ Britain's male youth demographic situation is far less serious than in many other European countries; however, the number of young males in this cohort at its minimum in 1994 is about 17 percent below late 1980 levels. Consequently, wages paid to young workers, including new service personnel, may increase more rapidly than wages in the average working population. In simple economic terms, as the number of young workers declines, the equilibrium youth wage rate will increase. This relative wage effect elasticity is estimated at .3 percent. Average wages for youth, including

²¹Major combatants include SSBNs, SSNs, SSKs, frigates, destroyers, assault ships, and ASW carriers. The data include ships in retrofit or on stand-by for retrofit for two reasons. First, the relative number of refits has decreased since 1971. Excluding the number of ships in retrofit may falsely indicate a lower personnel-to-ship ratio. Second, a small percentage of RN ships continues to undergo refit. Excluding these ships ignores RN refit personnel requirements. In fact, the ratio of personnel per ship on station has decreased, implicitly indicating an increasingly less efficient (more personnel-intensive) refitting process.

²²There have been several studies on the relationship between cohort size and wages, including Smith and Welch, 1981; and Welch, 1979.

²³The majority of personnel for the active forces comes from the 16-19 age group. House of Commons Defence Committee, 1985, p. 68.

²⁴The effects of this are already being felt in some industries, especially nursing and teaching. *The Economist*, 1988b, 1988c.

wages paid to young service personnel, should increase .3 percent for each 1 percent fall in the number of male youths.²⁵

The share of service personnel affected by this wage increase (the share of personnel from affected cohorts) is 50 percent in 1995, 100 percent in 2000, and 50 percent in 2005. These estimates are based on two principal assumptions: first, a 10 year average term of service.²⁶ By 1995, 50 percent of current active personnel will have been replaced by new recruits from affected cohorts; and all current active personnel will have been replaced by the year 2000. Second, in the long term, the British economy substitutes away from young workers, thereby lessening demand and their relative wages. Consequently, the number of youths affected by relative wage increases falls after the year 2000.²⁷

A second wage increase is forecast based on an MoD requirement to attract a higher percentage of young workers. For example, the MoD currently attracts about 7 percent of the 16 to 19 year old cohort. As this cohort declines, the MoD will have to attract a larger share, perhaps up to 10 percent.²⁸ To attract a higher share, the MoD will need to offer additional cohort-related wage increases; it is assumed that cohort effect elasticities will be .2 and .4 for enlisted personnel and officers, respectively.²⁹ For each percentage decrease in the youth cohort and in the absence of reductions in the number of required accessions, enlisted personnel and officer wages should increase .2 and .4 percent, respectively. The number of service personnel affected increases from 50 percent of all military careerist personnel in 1995 to 100 percent in 2000, and then decreases to 50 percent in 2005. As noted above, this assumes a 10 year average term of service and an eventual decline in the demand for and wages of youth workers, including service personnel.

In addition to these cohort-related increases, the MoD will maintain pay comparability with the civilian sector. Wage increases resulting from general economic conditions, based on economic growth and work force composition, are estimated at 1.7 percent per year. Estimated magnitudes of relative wage and cohort effects are illustrated in Fig. 7. Increases due to general economic conditions are not shown.

A high expenditure scenario assumes that wages increase by the relative wage and cohort effects described above in addition to increases due to general economic conditions. A low expenditure scenario assumes that wages increase only because of general economic conditions. A middle expenditure scenario assumes wage increases due to general economic conditions are one-half of the estimated increases from relative wage and cohort effects described above.

Table 10 summarizes high, middle, and low active personnel expenditures based on changes in requirements, relative wage, cohort, and general economic condition increases de-

²⁵The magnitude of this increase is based on previous work at RAND that examined potential relative wage effects in the United States. Tan and Ward, 1985. Wage effects will probably be comparable in Britain and other European countries. The baseline measure of the number of male youths is 1990.

²⁶This is comparable to estimated average terms of service in other NATO countries, including the United States.

²⁷The year in which the decline in demand for youth labor has been set somewhat arbitrarily. In addition to a decreased demand for youth labor after the year 2000, the relative wage effect should dampen somewhat over time and decrease the number of personnel affected by relative wage increases.

²⁸House of Commons Defense Committee, 1985, p. 69. The MoD has recently begun television advertising to increase its recruitment share.

²⁹The magnitude of this cohort effect is based on Tan and Ward's research. The cohort effect is slightly overstated in the low personnel expenditure scenario since a reduction in requirements reduces recruiting share. It is also slightly understated in the high expenditure scenario for the same reason.

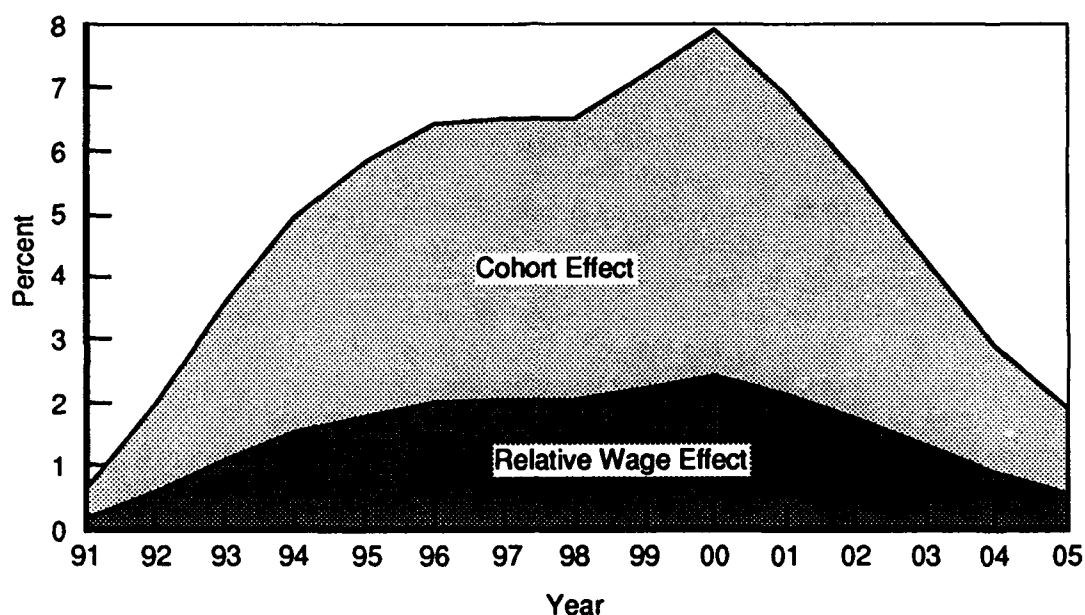


Fig. 7—Relative wage and cohort effect

scribed above. The major difference in expenditures results from decreases in personnel—relative wage and cohort effects are important, although less so than changes in the number of personnel.

Table 10
MODEL ESTIMATION OF ACTIVE
PERSONNEL EXPENDITURES
(Millions of £1987)

Expenditure Scenario	Change in Personnel (percent)	Cohort/Relative Wage Effects	Expenditures, 1990-2005
High	.2 ^a	Maximum	80,995
Middle	0	Modest	78,125
Low	-1	None	70,210

^a3 percent increase in personnel between 1990 and 2005.

Model Estimation of Civilian Personnel Expenditures

A sharp decrease in the number of civilian personnel partly explains the declining personnel costs in the U.K. since 1979. The number of civilian MoD personnel fell from 330,000 in 1971 to 173,400 in 1989, a 3.4 percent average annual decrease. This trend will probably

not continue at its current pace, although more modest reductions are possible.³⁰ Recent expenditure plans indicate little additional defense-related privatization or use of contractors.³¹

Civilian personnel requirements may continue to fall in the short term, up to perhaps 2 percent per year. Current government policy indicates at least some additional reduction. A high expenditure scenario estimates no decline in civilian requirements; a low expenditure scenario estimates a 2 percent per year decline to 2005.³² A middle case expects a 1 percent annual decline.

Historical data indicate that real civilian wages have increased roughly in line with per capita GDP growth, averaging 2.5 percent since 1971.³³ Continued increases of this magnitude are forecast in a high expenditure scenario. A low expenditure scenario forecasts considerably slower average annual growth of 1 percent. A middle scenario forecasts civilian wage growth of 1.7 percent per year. The middle case forecast is based on future work force composition and projected economic growth rates.³⁴ Table 11 summarizes high, middle, and low civilian expenditure forecasts based on changes in personnel and average wages.

Table 11
**MODEL ESTIMATION OF CIVILIAN
PERSONNEL EXPENDITURES**
(Millions of £1987)

Expenditure Scenario	Change in Personnel (percent)	Change in Wages	Expenditures, 1990-2005
High	0	2.5	33,730
Middle	-1	1.7	28,820
Low	-2	1.0	25,015

PROCUREMENT

The U.K. procurement category in 1989 represented 44.2 percent of total expenditures. In the early 1970s, procurement averaged in the low to mid 30 percent range. Procurement includes new equipment purchases, maintenance, and all research and development. This section addresses land, air, sea, and miscellaneous procurement categories.³⁵

³⁰Chalmers, 1987, p. 22, argues that future reductions will be modest at best.

³¹See *The Government's Expenditure Plans 1988-89 to 1990-91*, 1988, pp. 77-88.

³²This represents a total reduction of 29 percent over 16 years.

³³Civilian MoD real wage growth has been higher since 1980, averaging 2.7 percent per year. Increases were particularly high in the early 1980s. This apparent steep increase has resulted from the termination of many low salaried employees, creating a higher average salary.

³⁴These same assumptions were used in estimating future active force wage growth.

³⁵All data in this section are net expenditures. In some cases, however, net production expenditures for major equipment items are unavailable and have been estimated. For example, land production includes several gross expenditure equipment categories and a figure for land production aid. (Aid signifies assistance to other countries.) In most cases, aid is assumed to be distributed evenly across all gross production categories and net expenditures are adjusted accordingly.

Miscellaneous Procurement

Miscellaneous procurement includes administrative costs,³⁶ some minor contact procurement not covered in other areas, outstation procurement, and basic research and development expenditures, which constitute roughly one-half of miscellaneous procurement expenditures. Miscellaneous procurement expenditures averaged £960 million in the 1970s, with a slight increase to £1,080 in the last decade. Basic research and development should remain constant or decrease slightly in real terms,³⁷ so future miscellaneous procurement expenditure is estimated at its historical average of £1,024 million.³⁸

Land, Air, and Sea Procurement

Land Procurement. Land procurement has maintained a 23.5 percent share of Land, Air, and Sea procurement expenditure since 1971. It is broken down into development and production categories, including guns and small arms, ammunition, fighting and load-carrying vehicles, surveillance and communication equipment, guided weapons, other minor procurement, and maintenance.

Development share of land procurement has increased substantially since 1971. In the 1970s, it averaged 10.5 percent but has increased about 4.2 percent annually to a 1980s average of 17.2 percent. The model estimates that the ratio of development to production costs continue to increase, although at only one-half the rate since 1971. Land development share of land procurement should reach 24 percent in 2005.

The sophistication of many new Army equipment items may explain this increase in development expenditures. For example, in the early 1970s, communication and other electronic equipment took up a fairly small share of total Army production; however, today, communication and surveillance systems alone account for about 20 percent of all production spending. The introduction of additional high technology items, such as the MLRS I, Rapier upgrades, and the Ptarmigan communication system indicates a continued increase in weapon system development to production costs.

Many Army minor equipment items have been funded at fairly constant levels in real terms since 1971. For example, expenditures on small arms, ammunition, surveillance, engineering and communications equipment, load-carrying vehicles, and other minor items have increased only slightly in real terms. Some minor equipment items indicate a less than constant level of funding; however, many of these indicate a cyclical funding nature. Based on historical data, annual increases in minor equipment expenditures are estimated at 1 percent per year on a 1989 baseline of £593 million.³⁹ Figure 8 illustrates land minor procurement expenditure.

³⁶This includes sales promotion and staff salaries, among other things.

³⁷The U.K. is considering privatizing several R&D laboratories as a cost-savings measure. *Jane's NATO Report*, 1988.

³⁸The average includes negative miscellaneous procurement expenditure in 1971 resulting from exceptionally high aid to other nations.

³⁹This rate of increase reflects the average real increase for these items since 1971 adjusted for the high level of Ptarmigan spending in the mid to late 1980s. Ptarmigan expenditure was a one-time event, and this expenditure is not included in determining average future communication systems expenditure. Average 1971-89 expenditures are also adjusted downward to account for maintenance expenditures not reported in the *Supply Estimates* until 1982. I assume that the early *Supply Estimates* spread maintenance spending evenly across all categories listed under land procurement.

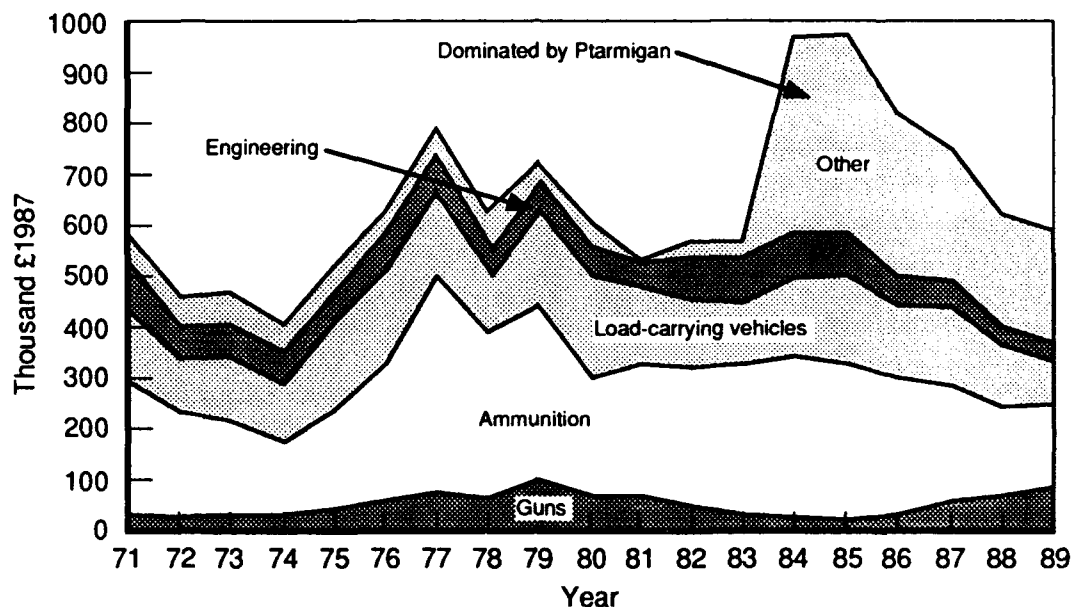


Fig. 8—Expenditure on land minor equipment items

Data on the maintenance share of the land procurement budget are limited, although maintenance expenditures accounted for 16.8 percent of 1981-1989 land procurement expenditures. Maintenance expenditures have increased their share of land procurement since 1981, although only slightly, and continued maintenance spending is estimated at its 1980s share of land procurement.⁴⁰

In sum, the model accounts for development, maintenance, and minor equipment procurement. Residual land procurement expenditure is available for the procurement of all armored vehicles and guided weapons.

Air Procurement. Air procurement, including development and production expenditures, has maintained an average 45.8 percent share of land, air, and sea procurement since 1971. Air production includes spending on fixed wing aircraft, helicopters, avionics and electronic equipment, guided weapons, and maintenance and support.

This category includes air equipment expenditures for the Royal Navy's Fleet Air Arm (Sea Harriers) and for the Army (support helicopters). According to testimony in Parliamentary hearings,⁴¹ these expenditures account for 20 percent of the air procurement budget. RAF air procurement totals only about 80 percent (about £2.4 billion in FY89) of the

⁴⁰Maintenance costs for more modern items, such as the Challenger tank, may not be less than that for older Chieftain tanks. Consequently, maintenance share of spending may increase. For example, while field maintenance for main battle tanks has apparently declined, regular base maintenance has increased. See House of Commons Defense Committee, 1985, p. 203.

⁴¹House of Commons Defense Committee, 1985.

total air procurement budget. This procurement is included on behalf of other services in the model.

Air development expenditures have averaged 23.1 percent of air procurement since 1971. Development spending occupied a greater share of air procurement in the 1970s, probably as a result of the Tornado's early development phase. The average in the 1970s was 26.5 percent, and this has fallen to 20.1 percent in the 1980s.⁴² Development share has increased since 1984, probably a result of both Tornado F.3 and EFA development. We assume a future development share of 23.1 percent.

Expenditure on aircraft weapons, avionics, and other electronic equipment production occupies a considerable share of the total RAF air procurement budget. After falling to a low of 12 percent in 1975, this category's share of total air procurement steadily increased to an average of 33.6 percent in the 1980s. Of course, some of this later increase can be attributed to the decrease in aircraft production spending as the Tornado entered service; however, increased weapons, avionics, and other electronic equipment spending began long before Tornado peak spending in the late 1970s and early 1980s, indicating that this would have occurred in the absence of Tornado as well. Aircraft weapons, avionics, and other electronic equipment are estimated to take up their historical average of 29 percent of air procurement funding.⁴³ Weapons, avionics, and electronic equipment costs for future air equipment items should remain flat relative to expenditures on aircraft platforms.

Finally, although only limited data (1984 to 1989) are available, air support and maintenance are estimated at 25.5 percent of all RAF air procurement. This equals the historical average.

In sum, the model accounts for all air development, weapons, avionics, electronic equipment, and maintenance spending. The air residual represents funding available for the purchase of all platforms, including helicopters for the RAF.

Sea Procurement. Sea procurement has taken up about 30.7 percent of land, air, and sea procurement expenditure since 1971. Sea procurement includes development and production spending, and production is broken down into spending on new equipment, such as hulls and weapon systems, and other spending, such as maintenance, miscellaneous stores, and minor procurement items.

Sea development's share of total sea procurement has increased from an average level of 11.9 percent in the 1970s, although it has risen to 19.4 percent in the 1980s. This represents an average yearly increase in development's share of total procurement of just over 3.3 percent.⁴⁴ It is uncertain whether this trend will continue into the next two decades.

⁴²Approximately two-thirds of Air Procurement development funding has been spent on aircraft development. The remainder has been spent on weapons, avionics, and other items. For the purposes of this analysis, I have assumed that air development continues to occupy 23.1 percent of all air procurement expenditure. This level of funding may not be sufficient for RAF future plans. Specifically, EFA development cost growth, if similar to that for Tornado, may consume the entire development budget and leave no residual funding for other projects. For example, in a high defense budget scenario (2 percent defense budget growth), total available RAF development funds from 1990 to 1998 (EFA development period) will be only about £8 billion. Even if this is devoted entirely to EFA, it may be insufficient given Tornado development cost estimates of £6 billion. This, of course, assumes EFA development costs greater than those for Tornado. See Aviation Advisory Service, 1983.

⁴³This estimate may be too conservative, given recent estimates that avionics alone may account for about 50 percent of spending on the EFA. Avionics, weapons, and electronic equipment expenditure may exceed aircraft platform expenditure.

⁴⁴A fairly trivial amount, perhaps £800 million, of 1980-1989 development spending has gone to Trident. See House of Commons, 1987, p. vii.

Increasingly complex shipborne weapon systems indicate probably continued increases in development share.⁴⁵ Continued development growth is estimated in relation to production, although at one-half the rate from 1971 to 1989, or 1.7 percent. This leads to a development share in 2005 of 25.0 percent. Increased development expenditure is likely considering Trident, SSN, destroyer, and frigate development requirements.

Sea production's share of total sea procurement will fall as development costs increase; however, production will nevertheless maintain about three-quarters of total procurement. A considerable portion of sea production will be taken up by overhead items, such as maintenance and minor procurement. The remainder will be available for the production of major equipment, such as hull production of SSKs, SSNs, SSBNs, and surface ships.⁴⁶

Shipborne weapons have taken up about one-third (34 percent) of total sea procurement expenditure since 1971. The average in the 1970s was 34.2 percent; this has fallen slightly to 33.7 percent in the 1980s. A 34.0 percent weapons share is forecast to 2005, equal to the historical average.

Maintenance and other support for sea systems similarly have maintained a stable share of sea production. In the 1970s, maintenance and other support averaged 28.0 percent of sea production; in the 1980s, it has fallen, albeit only slightly to 26.1 percent.⁴⁷ There is no apparent trend in maintenance or support, nor is there any reason to expect any substantial change in the future; therefore, maintenance and support should maintain roughly the 1980s average 26.1 percent share of sea production.

In sum, the budget model accounts for ship development, weapons and minor systems procurement, and all maintenance and support costs. The sea residual represents available resources for the procurement of ship hulls, including major surface combatants and submarines.

SUMMARY OF MODEL ESTIMATES AND RESOURCES IN THE MIDDLE CASE SCENARIO

Table 12 summarizes model structure and lists middle case values. The major equipment production residual, £21,480 million, represents resources for the production of ship and submarine hulls, armored vehicles, Army guided weapons, and RAF platforms in the middle-case scenario.

⁴⁵See Pugh, 1986, p. 346, for a discussion of ship development costs.

⁴⁶Procurement for RN/M air systems is included in the Air Equipment section.

⁴⁷Lower maintenance costs may have resulted from a decrease in the number of RN ships.

Table 12
DEFENSE BUDGET MODEL CATEGORIES, DEFINITIONS,
AND MIDDLE CASE VALUES

Variable	Definition	Derivation	Middle Case, 1990-2005 (£1987 millions) ^a
B	Defense budget	Exogenous	320,330
O	Operations	$.205 \times \text{Defense}$	65,670
R _r	Retired personnel	Exogenous	21,300
R _a	Active personnel	Exogenous	78,130
R _c	Civilian personnel	Exogenous	28,820
P	Procurement	$B - O - R_r - R_a - R_c$	126,415
P _s	Miscellaneous equipment	Exogenous	16,385
P _m	Major equipment procurement	$P - P_s$	110,030
L	Land equipment	$.235 \times P_m$	25,840
L _d	Land development	$.172 \times L^b$	5340
L _e	Minor land equipment	Exogenous	9585
L _m	Land maintenance	$.168 \times L$	4340
L _r	Land residual	$L - L_d - L_e - L_m$	6580
A	Air equipment	$.458 \times P_m$	50,360
A _x	RN, Army air equipment	$.2 \times A$	10,070
A _r	RAF air equipment	$A - A_x$	40,290
A _d	Air development	$.231 \times A_r$	9305
A _w	Air weapons, etc.	$.29 \times A_r$	11,685
A _m	Air maintenance	$.255 \times A_r$	10,275
A _r	Air residual	$A_r - A_d - A_w - A_m$	9025
S	Sea equipment	$.328 \times P_m$	33,755
S _d	Sea development	$.194 \times S^c$	7595
S _w	Sea weapons	$.34 \times S$	11,475
S _m	Sea maintenance	$.261 \times S$	8810
S _r	Sea residual	$S - S_d - S_w - S_m$	5875
M	Major equipment production	$L_r + A_r + S_r$	21,480

^aSome numbers are rounded.

^bGradually increasing to .24 by 2005.

^cGradually increasing to .25 by 2005.

V. RESOURCES, REQUIREMENTS, AND CONVENTIONAL FORCE REDUCTIONS

Previous sections outlined British military modernization requirements and a range of budgetary resources. They did not consider the effects of conventional arms control agreements in Europe. This section examines the potential effects of conventional force reductions in Europe on Britain's modernization requirements and defense resources. Conventional arms control will very likely reduce Britain's modernization requirements. Similarly, arms control agreements will almost certainly influence defense resources. To simplify the analysis, the discussion is limited to a middle case requirement and resource scenario.¹

CONVENTIONAL FORCE REDUCTIONS IN EUROPE

An agreement reducing conventional forces in Europe appears probable in the very near future.² NATO and Warsaw Pact negotiators at the CFE discussions in Vienna have agreed in principle to first stage reductions involving main battle tanks, armored troop carriers, and artillery. Warsaw Pact force reductions would be about 50 percent, while NATO-wide reductions would be about 10 percent. Negotiators have not agreed to, but continue to discuss, 15 percent reductions in the number of combat aircraft³ and helicopters. These agreements correspond largely to the NATO proposal advanced in March 1989 and to President Bush's subsequent proposal in May 1989.

The Warsaw Pact has not only largely agreed to the NATO proposal but has suggested second and third stage reductions of greater magnitude.⁴ Warsaw Pact negotiators have suggested Phase II reductions of an additional 25 percent in equipment and personnel. In Phase III, Warsaw Pact negotiators suggest further reductions and a restructuring to defensive postures. Warsaw Pact and NATO negotiators have agreed in general terms to reductions beyond Phase I—although discussions on Phase II and III reductions have been informal, further reductions of 50 percent have apparently been discussed.⁵ This analysis addresses CFE I reductions with 10 percent reductions for NATO in designated equipment and personnel.⁶

¹The assessment of requirements-resources imbalances in Sec. VI examines nine cases: high, middle, and low requirements and high, middle, and low resources (a three by three matrix). This section introduces two additional variables to account for uncertainty in modernization requirements following an arms control agreement. This would result in 18 scenarios.

²Such agreements are not inevitable, although the rapid pace of negotiations suggests that only major unresolved disputes between NATO and Warsaw Pact (or perhaps disputes within each alliance) will prevent agreement in the near to medium term.

³The main obstacle to agreement in this category is the difference in NATO and Warsaw Pact definitions of combat aircraft. The Warsaw Pact excludes interceptor and training aircraft from their total.

⁴The virtual disintegration of the Warsaw Pact casts doubts on the specific nature of these proposals. However, large reductions by individual members seem inevitable.

⁵Dean, 1989, p. 31.

⁶Fifteen percent for aircraft and helicopters.

CFE, BRITISH REQUIREMENTS AND RESOURCES

Specific national reductions in equipment and personnel will depend upon final definitions of armaments (such as the precise definition of main battle tanks) and the degree of reduction across participating nations (i.e., equal or unequal reductions across participants); however, CFE I will almost certainly reduce overall requirements and the costs of British modernization. Similarly, CFE agreements are virtually certain to reduce British defense resources as the perception of the likelihood of war in Europe decreases.

Requirements

CFE I is assumed to reduce British Army and Royal Air Force production requirements 10 percent for main battle tanks, armored troop carriers, and artillery; 15 percent for combat aircraft and helicopters.⁷ For example, CFE I would reduce the planned replacement of Chieftain main battle tanks from 500 to 450 and would reduce Britain's EFA procurement from 250 to 213. (Corresponding reductions in minor equipment and other expenditure categories, including personnel, are included in the next section since these affect major equipment production resources as defined by the residual budget model.)

A second case assumes that CFE I reductions of 10 and 15 percent will apply to all Army and Air Force equipment, respectively, whether included in or excluded from CFE negotiations. Similarly, although almost all naval equipment is excluded from CFE, 10 percent reductions are included in Royal Navy and Marine modernization requirements.

Specific reductions in the production of major equipment under CFE I should result in equivalent reductions in expenditures. For example, a 10 percent reduction in main battle tank requirements leads to a 10 percent reduction in estimated 1990–2005 expenditures on main battle tanks.⁸ Table 13 shows estimated British CFE I major equipment production requirements in the middle case scenario (i.e., 5 percent annual cost growth to system in-service date is included). CFE I(a) and CFE I(b) represent the first and second cases, respectively. As Table 13 indicates, aggregate requirements decline between 5 and 12 percent.

Resources

Agreement to reduce conventional forces in Europe will probably lead to decreases in available resources in NATO Europe, including Britain, as the perception of the likelihood of war in Europe declines. Britain's aggregate defense spending, fairly constant since 1985, may begin to decline in real terms under CFE agreements, particularly with large force reductions in CFE Phases II and III. It is difficult to assess the potential magnitude of these reductions, although eventual decreases of perhaps several tens of percent (roughly corresponding with force reductions in CFE) may occur.

⁷Geographic limits on forces may in fact result in less than 10 percent reductions for nations with stationed forces in Central Europe, according to unpublished RAND analysis.

⁸This may be a somewhat optimistic assumption since current equipment cost estimates reflect current expected production runs. Shorter production runs, particularly for aircraft, are likely to result in higher per unit costs. Thus, a 10 percent reduction in requirements may lead to less than a 10 percent reduction in expenditures.

Table 13
MIDDLE CASE BRITISH REQUIREMENTS
UNDER CFE ASSUMPTIONS^a
(Millions of £1987)

Service	Current	CFE I(a)	CFE I(b)
Army	8475	7905	7630
Royal Air Force	16,605	14,815	14,115
Royal Navy	19,100	19,100	17,190
Total	44,185	41,820	38,935
Percent change from current requirement	—	-5.35	-11.88

^aThese requirements reflect accounting adjustments as outlined in App. D. Some numbers are rounded.

This analysis assumes that aggregate British defense budgets under a CFE I agreement increase at the rate of 1 percent per year. (This reflects the same rate of growth in the middle case earlier in this report and may be unrealistic following a CFE I agreement.) Further, CFE I is assumed to result in average 10 percent reductions between 1990 and 2005 in many other budget categories, including operations, active and civilian personnel, miscellaneous procurement (primarily basic R&D), minor land equipment, and land helicopters. (Reductions are assumed in these last two categories as they may be related to aggregate land procurement.) Construction of a residual budget model causes resources for major equipment production to increase.

Under these assumptions, resources for the production of major equipment items are projected at £27,040 million from 1990 to 2005, and a range of requirements under CFE I of £38,935 to £41,820.

VI. THE RESOURCE-REQUIREMENTS IMBALANCE

Section II estimated major equipment production requirements for the next 15 years. Some minor accounting adjustments, due to differences between service and geographic procurement accounts, as highlighted in Appendix D, are necessary in order to contrast these requirements with available resources. These accounting adjustments result in a slight decrease in requirements. For example, middle case requirements in the absence of arms control fall from £48,445 to £44,185 million.

RESOURCE-REQUIREMENTS IMBALANCE IN THE ABSENCE OF ARMS CONTROL

Major Equipment Funding Shortfalls

Table 14 illustrates major equipment requirements and contrasts these with resources as estimated by the defense budget model. These figures represent the difference between major equipment production resources and requirements.

The matrix in Table 14 indicates a variety of resource-requirements results. Available resources for major equipment, as calculated in the budget model, are listed across the top. These high, middle, and low resource scenarios incorporate corresponding personnel cost growth scenarios as explained earlier. Requirements for major equipment, as estimated in Sec. II and adjusted from service to geographic requirements, are listed along the left side of the table.

Funding shortfalls across land, air, and sea budget categories may roughly indicate Army, Air Force, Navy and major equipment funding shortfalls, respectively. Such an assessment is speculative since a 1985 MoD reorganization established a more centralized resource allocation process. Although this centralized allocation process casts doubt on each category's (or service's) ability to maintain its historical share of MoD procurement funding, remaining institutional pressures suggest and recent data indicate a rough continuation of

Table 14
MAJOR EQUIPMENT FUNDING SHORTFALL
(Millions of £1987)^a

Requirements Scenario	Resources Scenario		
	High (29,540)	Middle (21,480)	Low (9965)
Low (34,515)	4975	13,035	24,550
Middle (44,185)	14,645	22,705	34,220
High (51,760)	22,220	30,280	41,795

^aSome numbers are rounded.

this historical division of the procurement budget. In the middle case, land, air, and sea shortfalls represent 8, 34, and 59 percent shares of the total shortfall. Land, air, and sea average historical shares of total major equipment production are roughly 24, 46, and 31 percent,¹ respectively; thus, the sea category (roughly corresponding to the Royal Navy) appears to be the most underfunded based on projected shortfall to production share ratios.

Defense Budget Shortfalls

These equipment shortfall figures represent the difference between major equipment production resources and requirements and understate additional increases in aggregate defense spending necessary to eliminate major equipment production shortfalls. This additional increase in aggregate defense spending is necessary because several variable expenditure categories have been included in the budget model such as maintenance, minor equipment production, and operations. Defense budget shortfalls may be as much as four and one-half times greater than major equipment shortfalls. (This multiplier effect reflects the structure of the defense budget model, which includes several variable expenditure categories. Including these variable categories greatly increases the difference between major equipment production and defense budget shortfalls. Excluding some variable expenditure categories reduces the multiplier effect. Appendix E describes the relationship between major equipment production and defense budget shortfalls.)

Table 15 indicates aggregate defense budget increases necessary to eliminate major equipment shortfalls and to pay for variable expenditures, including development, maintenance, minor equipment production, and operations expenditures. The format of Table 15 corresponds directly to that in Table 14 except that requirements and resources figures are not displayed since resources vary across all cases.

Table 15 indicates aggregate defense budget shortfalls roughly four and one-half times greater than major equipment shortfalls described in Table 14. For example, in the middle case, the shortfall is roughly 32 percent of aggregate spending during the 1990-2005 period. In the high requirement-low resource case, the aggregate defense budget shortfall represents a 66 percent budget shortfall. In the low requirement-high resource case, an approximate £22 billion shortfall represents 6 percent of aggregate spending.

Table 15
DEFENSE BUDGET FUNDING SHORTFALL
(Billions of £1987)^a

Requirements Scenario	Resources Scenario		
	High	Middle	Low
Low	22,165	58,095	109,405
Middle	65,255	101,185	152,495
High	99,010	134,940	186,250

^aSome numbers are rounded.

¹Numbers are rounded and do not sum to 1.

Temporal Distribution of Shortfalls: Middle Case

A comparison of spendout rates for major equipment production with resources estimated by the budget model provides a crude measure of major equipment production shortfalls over time in the middle case.

In order to assess the magnitude of requirements over approximate five year intervals, production expenditures are assumed to correspond directly with initial operational capability dates discussed earlier. For example, production expenditure for Swingfire (a land system) falls in 1997, or in the 1996-2000 time period.² Estimated spendout rates for equipment demonstrate an uneven shortfall distribution over the 15-year period. In particular, estimated shortfalls appear the greatest in the 1990-1995 period. Table 16 indicates estimated shortfalls for approximate five-year periods in the middle case scenario.

The largest estimated middle case equipment shortfall occurs in the 1990-1995 period.³ This corresponds with the initial operational dates of several equipment requirements, including Trident, Type 23 frigate, Rapier, M-SAM, C-130 replacement, and the Army's main battle tank purchase. The major equipment production shortfall in this period is estimated at £14 billion, or 62 percent of the aggregate 1990-2005 shortfall. Estimated equipment shortfalls in the other two periods are comparable in magnitude. (The MoD may slip the IOC of early 1990s systems, resulting in a more even distribution.)

Table 16
TEMPORAL DISTRIBUTION OF EQUIPMENT SHORTFALLS:
MIDDLE CASE
(Millions of £1987)^a

	1990-1995	1996-2000	2001-2005
Requirements	22,375	11,445	10,365
Resources	8255	6660	6565
Shortfall	14,120	4785	3800

^aSome numbers are rounded.

REQUIREMENTS-RESOURCES IMBALANCES UNDER CFE I

Major Equipment Funding Shortfalls

Table 17 illustrates major equipment requirements and contrasts these with resources as estimated by the defense budget model. These figures represent the difference between major equipment production resources and requirements defined according to arms control assumptions in Sec. V.

Substantial shortfalls persist under these assumptions. CFE agreement will reduce defense budget shortfalls from 32 percent (my estimated middle case figure in the absence of arms control) to between 17 and 21 percent. (These figures reflect a 1 percent average

²There are minor exceptions to this rule. For example, large expenditures, such as EFA, SSN-20, and Type 42 and 82 destroyer replacements have been spread over ten rather than five year periods.

³If resources are averaged over the 15 year period, the magnitude of the 1996-2000 shortfall diminishes, although it remains much greater than shortfalls in other periods.

Table 17
MAJOR EQUIPMENT AND DEFENSE BUDGET SHORTFALLS:
CFE I REQUIREMENTS

	CFE I(a)	CFE I(b)
Major equipment requirements	41,820	38,935
Major equipment resources	27,040	27,040
Major equipment shortfall	14,780	11,895
Defense budget shortfall	65,865	53,005
Defense budget shortfall/defense spending	20.6%	16.5%

annual increase in aggregate defense spending. Lower annual increases, arguably more likely following CFE agreement, result in larger shortfalls.) A CFE I agreement will reduce British modernization requirements and major equipment and defense budget shortfalls; however, it will not eliminate them. Further reductions in requirements, such as those discussed in CFE II and III, increases in resources, or both may be necessary to avoid future shortfalls. In fact, without further reductions in requirements beyond CFE I, aggregate defense spending must increase at slightly more than 3 percent per year to eliminate shortfalls in either CFE I scenario.

Reductions in British defense resources, possibly more likely after a CFE I agreement, may exacerbate shortfalls. For example, if one assumes CFE I(b) requirements (a 12 percent reduction in major equipment requirements) and flat aggregate defense budget resources, then equipment and defense budget shortfalls increase to £16,535 and £73,685, respectively. The latter represents a 25 percent defense budget shortfall.

NATURE OF THE MODEL AND REQUIREMENTS

The conservative nature of the model and conservative assessments about major equipment requirements may understate the magnitude of funding shortfalls. For example, this study uses optimistic assumptions about many minor procurement items expenditures,⁴ and it assumes land and sea development cost growth increases at only one-half the historical rate. These assumptions may overstate major equipment production resources.

Conservative requirement estimates also may contribute to understating major equipment and budget shortfalls. As indicated in Sec. II, for example, items already in production were assumed to incur no additional cost growth. As outlined earlier, modest cost growth after initial production is not uncommon. Similarly, the lowest available production costs have been used. Finally, estimating requirements over this long time period invariably tends to understate requirements in distant out-years. For example, although this study mainly examines requirements from 1990 to 2005, 95 percent of requirements fall in the first 10 years, or 67 percent, of the time period.

⁴For example, the model assumed that Britain's nuclear modernization program outside of Trident does not increase its relative share of the budget. Considering Britain's collaborative development with France of a nuclear standoff weapon and its associated costs, this may be an optimistic assumption.

Requirements-resources tables indicate a fairly wide range of shortfalls, although these can be narrowed. For example, in the absence of an arms control agreement, the major equipment and defense budget tables indicate low requirement-high resource shortfalls of £5 and £22 billion, respectively. This assumes the best of many worlds—2 percent per year real defense budget growth,⁵ no minor or major equipment cost growth, and no increases in active force wages despite the declining youth cohort. The likelihood of these occurring simultaneously is small.

Middle case shortfalls are more likely. Requirements based on modest annual equipment cost growth of 5 percent are probable, given historical experiences. Similarly, historical evidence strongly suggests modest or perhaps flat budget growth. Finally, as incorporated in the middle case, Britain's declining youth population is likely to exert some pressure on military wages, which will lead to decreases in major equipment production resources. Thus, major equipment production shortfalls of £22 billion (an annual shortfall of £1.4 billion) and defense budget shortfalls of £100 billion (an annual shortfall of £6.3 billion) are more likely. The range of shortfalls under CFE I represents middle case (most likely) requirements and higher than likely resources, and may thus somewhat understate shortfalls.

⁵The U.K. has maintained 2 percent per year or greater defense budget growth for only six consecutive years of the last 35.

VII. REACTIONS TO SHORTFALLS

Substantial budget shortfalls may force MoD planners to make difficult choices, ranging from stretching out procurement purchases to reductions in readiness or curtailing the level of effort in some missions. Increased efficiencies, particularly decreases in personnel and operating costs, may reduce the need to take such drastic action as would reductions across nondefense budget categories by central planners in the Ministry of the Treasury.

INCREASED EFFICIENCY

The MoD has already begun several efforts for increasing the efficiency of the U.K. defense effort. Measures include more efficient military operations, a more efficient U.K. procurement process, and the improved use of military personnel.

More Efficient Operations

The MoD recently announced an efficiency measure designed to decrease operating expenditures (all noninvestment expenditures, including personnel). Specifically, the MoD hopes to reduce all noninvestment expenditures (about £12 billion annually) 2.5 percent per year over the next three years.¹ This is expected to be accomplished by various management initiatives, rationalization of service requirements, organizational changes, and the contracting out of certain required services. The MoD also plans an additional 1.5 percent per year reduction in military and civilian personnel, fuel, utilities, and some support expenditures (about £5 billion annually) in the next two years. Accomplishing these reductions will be difficult, although the rewards will be substantial. For example, these wide-ranging efficiency gains would reduce the middle case major equipment production shortfall in the absence of arms control from £23 to £14 billion.² The defense budget shortfall would decrease to £62 billion, 20 percent of aggregate spending. Although these measures would not eliminate shortfalls, even under arms control assumptions, they would reduce shortfalls greatly.

A More Efficient Procurement Process

A more efficient U.K. procurement process may also decrease financial requirements. Savings may result from procurement reorganization within the MoD, increased competition among producers, or an increase in collaborative production efforts.

A 1985 reorganization of the MoD instituted several changes intended to streamline the procurement process and reduce institutional barriers within the MoD.³ Perhaps the most

¹HM Treasury, 1989. Permanent reductions in maintenance, operations, and other variable expenditure categories to constant expenditures (e.g., annual RAF maintenance expenditures of £500 million regardless of RAF procurement) would greatly reduce future shortfalls. Historical data demonstrate variable relationships, however, suggesting that such reductions may be difficult.

²Reductions in the retired personnel account will remain difficult and have been excluded from these figures.

³*The Central Organization for Defence*, 1985.

important step was the establishment of the Office of Management and Budget within the MoD. The OMB, unlike its U.S. counterpart, has replaced the individual service staffs in evaluating equipment requests and is the centralized planning organ in MoD procurement policy. This and other organizational changes may lead to savings.

Increased competition in U.K. defense industries may also alleviate any budget shortfall. However, the small number of defense contractors may limit savings, and the magnitude of these savings through increased competition is unclear. In general, the House of Commons (HC) is skeptical of the total savings from competition,⁴ while the MoD is encouraged by its prospects.

The U.K. has entered into several cooperative arrangements for the production of weapons, and the number of these will probably increase. In theory, of course, cooperative arrangements spread the fixed costs of systems across all participants and thus reduce program unit costs. For example, spreading the research and development costs for EFA across the U.K., FRG, Spain, and Italy might reduce U.K. program costs by perhaps 33 percent.⁵

More Efficient Use of Personnel

There is little doubt that the MoD will attempt to make great decreases in military and civilian manpower requirements. In particular, demographic factors will probably pressure planners to reduce the required number of active service personnel. However, the outlook for future efficiency gains, based on historical evidence, appears limited. Savings may occur as less personnel-intensive equipment is introduced or as reserve forces, including the Territorial Army, are utilized more heavily.⁶ Savings achieved through more efficient personnel policies would provide modest savings. A 10 percent reduction in active force requirements, for example, would save about £8 billion between 1990 and 2005.⁷ This would reduce major equipment and defense budget shortfalls in the middle case to £21 and £92 billion, respectively. The latter figure represents a 28 percent defense budget shortfall.⁸

In sum, efficiency gains may mitigate a future defense budget shortfall, although the outlook for a substantial contribution toward this reduction by individual efficiency measures is not promising. Taken together, these measures would certainly contribute to more efficient defense operations. For example, 11 percent reductions in noninvestment expenses

⁴An HC report claimed that the Hesseltime reforms would save only enough by the 1990s to buy and operate one main battle tank. This is obviously hyperbole, but it reflected initial HC skepticism. The HC is now more optimistic about procurement savings. See Aviation Advisory Service, 1984.

⁵EFA development (£6 billion) and production costs (£6 billion) for the U.K. alone would be about £12 billion. Spreading development costs among other partners should reduce EFA development costs to £2 billion (a 33 percent British share), or an £8 billion total program cost. In reality, however, cooperative programs are often less efficient than envisioned for several reasons. First, they assume that participating members agree on the precise nature of the final product. Differences in national requirements, such as aircraft weight or mission objectives, often complicate the concept formulation and development phase, leading to a more costly and perhaps less capable final product. Second, such programs are subject to economic and political pressures within participating nations. For example, participants may disagree over the location of production facilities or the production responsibilities of participants. Invariably, political forces prevail, resulting in an inefficient allocation of resources and a higher final unit price. Hartley, 1983.

⁶The Labour Party would like to utilize more reserve forces. See, for example, *Defence without the Bomb: A Report of the Alternative Defence Commission*, 1983.

⁷Based on active personnel expenditures of £78 billion in the middle case.

⁸In addition to these active force reductions, 10 percent average reductions in civilian personnel expenditures would decrease major equipment and defense budget shortfalls to £19 and £86 billion, respectively.

(essentially the MoD goal in the next three years) and 10 percent reductions in military and civilian personnel would reduce pre-CFE I middle case shortfalls by roughly 50 percent, probably eliminating shortfalls under CFE I assumptions.

STRETCHING OUT NEW EQUIPMENT PURCHASES

Defense planners often react to financial shortfalls by "stretching out" new equipment purchases, or as British planners say, by "pushing it to the right" (of the ledger). Delaying production runs and initial operating dates allows planners to effectively reduce modernization requirements, although at the expense of current force structure and future resources. Force structure may suffer since equipment in need of replacement must remain in operation beyond its normal and perhaps useful operational lifetime. Future resources, depending on financing arrangements,⁹ may be carried forward to cover current requirements. Finally, stretching out purchases (usually through extended production runs) often results in higher per unit costs; thus, savings may be minimal.

British planners might choose to postpone several new equipment purchases in reaction to an expected shortfall. The projected pre-CFE I middle case equipment shortfall, £23 billion, could be substantially reduced to about £9 billion by postponing several equipment purchases as illustrated in Table 18.

The postponement of several major equipment purchases by as much as eight years greatly reduces projected shortfalls. However, the costs of these postponements are also substantial. For example, a postponement of EFA's in-service date to 2004 would force the RAF

Table 18
SAVINGS FROM EQUIPMENT POSTPONEMENTS
(Millions of £1987)

Equipment	Projected IOC	Costs	New IOC	Savings
EFA ^a	1999 ^b	9410	2004	7530 ^c
FFLAV ^d	1997-8	1625	2003	815 ^e
Trigat	1995	400	2003	200 ^e
SSN20	1998	3400	2005	1700 ^e
NFR-90	1997	2535	2002	845 ^f
ASW Frigate	2002	2695	2007	2695
Total				£13,785

^aAir defense and ground attack variant.

^bAverage of air defense and ground attack variant IOCs.

^cBased on payment on 50 aircraft before 2005.

^dReplacing Ferret, Scorpion, Fox.

^eAssumes 50 percent purchase before 2005.

^fAssumes 33 percent purchase before 2005.

⁹If today's requirements are paid for with tomorrow's money.

to continue to fly some Phantom air defense squadrons to perhaps as late as 2007, when the Phantom's average airframe age would reach 37 years.¹⁰ Clearly, the effectiveness of the Phantom in its air defense role would be brought into question.¹¹

REDUCING READINESS

The British might also reduce a shortfall by cutting the readiness of its forces. In particular, they might decrease maintenance and munitions expenditures in order to accommodate major equipment purchases.¹² (Considering Britain's commitment to ready forces, this option seems unlikely.) Table 19 illustrates savings resulting from 50 percent reductions in munitions and maintenance expenditures in the pre-CFE I middle-case scenario.

Reductions in both maintenance and munitions expenditures result in savings sufficient to eliminate the middle case shortfall (i.e., major equipment production resources increase to £44 billion). However, the potential costs of these measures are great. Equipment would often be unavailable for combat and would be more prone to breaking down. Similarly, reductions in munitions would damage combat capabilities.

Table 19
SAVINGS FROM READINESS REDUCTIONS, 1990-2005
(Millions of £1987)

Category	Munitions	Maintenance	Savings
Land	4,200 ^a	2,170	6,370
Air	1,750 ^b	5,140	6,890
Sea	5,750	4,405	10,155
Total			£23,415

^aAuthor's estimate of ammunition category expenditures.

^bAuthor's estimate.

REDUCTIONS IN MISSION COMMITMENTS

Reducing mission commitments may be considered as a last resort if efficiency gains, equipment stretch-outs, or reductions in readiness fail to eliminate or greatly reduce budget shortfalls. Although reductions in commitments are not being contemplated officially, reductions in BAOR, Army out-of-area, RAF ground attack, and Royal Navy blue water missions may occur. Reductions are more likely following a CFE agreement.

¹⁰And its design age would be 50 years.

¹¹If the British are able to meet the EFA timetable, Phantoms would retire at an average age of 32. Some might argue convincingly that a Phantom at 37 years of age is as capable as a Phantom at 32 years; however, stretch-out after stretch-out would eventually result in very old fighter aircraft and this is without question undesirable. Older aircraft also require additional maintenance—aircraft would very likely spend a great deal of time in hangars rather than on-station ready for combat.

¹²Deliberately reducing maintenance expenditures differs from efficiency gains described above. The latter case would cause no reduction in capabilities. The former case would have deliberate decreases in capabilities.

Considerable debate in Britain has recently focused on Royal Navy missions, and these are perhaps the most vulnerable to reductions.¹³ In late 1987, the MoD announced that it would not order the three frigates per year necessary to maintain the current surface fleet.¹⁴ The U.K. may slowly build down to a much-reduced surface Navy or, in the extreme case, it may choose to maintain only its submarine forces and homeland patrol boats. (Such actions would seriously affect forward maritime strategy.) Phasing out the surface fleet's blue water mission¹⁵ would reduce RN procurement requirements in the pre-CFE I middle case by at least £12 billion (£6 billion for ship development and production and £6 billion for weapons development and production) over the next 15 years. Operations and personnel savings would probably total nearly £1 billion per year, for a total reduction of £28 billion.¹⁶ Savings of this magnitude would eliminate all but the most extreme shortfalls (i.e., high requirement-low resource case pre- or post-CFE I) and allow the RAF and Army to actively modernize their forces. This alternative, of course, greatly reduces British naval forces, which supply 70 percent of NATO's early front-line naval forces.

The U.K. might consider Trident cancellation, although this is extremely unlikely.¹⁷ Cancelling Trident (which appears *far* from the minds of political leaders) would result in equipment savings of less than £5 billion in the unlikely event that all unspent funds are uncommitted. Operations savings might total £4 billion between 1994 and 2005. A Trident cancellation by a Labour government after the next elections in 1991 or 1992 also seems unlikely since savings would total less than £3 billion. The Labour Party apparently remains opposed to Trident, although some reports indicate that Labour would not scrap Trident if given the opportunity. Previously, the Labour party had claimed that Trident would reduce conventional force strength by 30 percent¹⁸ and strongly supported program termination.

Reductions in the strength of the BAOR are probable through conventional arms control, although consideration has also been given to reductions in its absence. Reducing BAOR strength by 50 percent, as some have suggested, would result in savings of near £1 billion per year *only if* these forces were disbanded.¹⁹ This alone would be sufficient to go forward with many Royal Navy and Royal Air Force equipment requirements. A reduced commitment in the absence of arms control agreements seems unlikely considering the staunch U.K. commitment to the 55,000 troop BAOR since 1962.²⁰

¹³Recently the *Economist* suggested that the MoD once again consider shrinking the Royal Navy's surface fleet as the least painful way of addressing the resource-requirements imbalance. *The Economist*, 1988a. For a pessimistic assessment of the Royal Navy's future, see George, 1988.

¹⁴Aviation Advisory Service, 1984 and 1987. This, of course, conflicts with commitments to a 50 frigate and destroyer surface fleet. *Statement on the Defence Estimate 1989*, Vol. I, p. 24.

¹⁵The Labour Party announced a contrary approach, suggesting that the RN abandon SSK and SSN missions. Foreign Broadcast Information Service, 1986.

¹⁶Operations and personnel savings between 1990 and 2005 inclusive, or 16 years.

¹⁷During my recent visit to the U.K., several officials and scholars suggested that this idea was not entirely far-fetched; however, I am quite skeptical given Thatcher's commitment to and public support for an independent nuclear force. Also, Labour has softened its anti-nuclear stance. For recent developments about Labour's softening position on nuclear weapons issues, see *Aviation Week and Space Technology*, 1989; Miller, 1989b and 1989d; *NATO Report*, 1988a and 1988b.

¹⁸Kinnock, 1987, p. 31. This is obviously hyperbole. While the operating (£10 billion) and equipment (£9 billion) costs of Trident over 30 years would reduce opportunities for conventional equipment, the reduction in conventional force equipment budgets is nearer 21 percent (based on conventional force reductions of £19 billion in equipment budgets of £90 billion).

¹⁹The costs of maintaining the BAOR at its current strength are estimated at about £2 billion per year, according to *Statement on the Defence Estimates*, 1989.

²⁰The British had planned to reduce the BAOR in 1961 to 45,000 but canceled it following the Berlin crisis. Coker, 1986, p. 6.

The RAF appears committed to maintaining its current missions, although marginal reductions might occur in the long term. For example, the Labour Party has argued in favor of a "defensive" RAF, which would fly only air defense missions while also possibly directly supporting ground troops.²¹ That would reduce RAF spending by about 30 percent and would also, of course, be a tremendous loss to NATO's central region air power.

Finally, reductions in joint out-of-area operations, such as those in the Falklands, would result in great loss of prestige and only modest savings. Out-of-area operations cost £400 million per year. Abandoning operations in Cyprus, Hong Kong, Belize, Brunei, Northern Ireland, or the Falkland Islands²² would result in minimal savings. It seems especially unlikely that the British will consider terminating their presence in the Falklands or Northern Ireland. Other commitments provide much prestige at little cost and are also unlikely to be reduced.

In summary, efficiency savings, particularly reductions in personnel and operations expenditures, can alleviate modest shortfalls. Stretching out equipment purchases reduces shortfalls considerably and is a likely MoD response, as is a combination of these measures. More drastic and less likely measures, including reductions in mission commitments and readiness, may be necessary if shortfalls are not remedied by efficiency gains or equipment stretch-outs. There will undoubtedly be great resistance to such actions; however, should they occur, further reductions in the Royal Navy's surface fleet are the most likely option.

CONCLUSIONS

CFE I will reduce Britain's modernization requirements, although continued modest growth in aggregate defense resources may still be necessary to achieve CFE I goals. Modernization requirements remain large, and shortfalls are likely to persist unless aggregate defense resources increase modestly. CFE I in itself may not be a panacea for Britain's potential defense budget problems, although it will contribute to shortfall reduction.

CFE II and III may drastically reduce Britain's military requirements and will in all likelihood eliminate any shortfalls; however, this again may depend on aggregate defense resources. CFE II equipment and personnel reductions of 25 percent and flat aggregate defense budgets eliminate shortfalls. CFE III reductions of 50 percent and flat aggregate defense budgets, of course, result in budget surpluses. However, defense budgets are unlikely to remain flat as Warsaw Pact reforms continue and potentially large shortfalls may persist.

This discussion is based on results from the budget model and therefore does not consider efficiency gains, stretching out equipment purchases, readiness reductions, or marginal reductions in Britain's military commitments as discussed in Sec. VI. Such measures will in all likelihood reduce the magnitude of projected shortfalls, and in conjunction with CFE I they may eliminate future shortfalls. For example, reductions in equipment and personnel requirements of about 10 percent (as outlined in CFE I), efficiency gains of a similar magnitude, and modest delays in the in-service dates of new equipment will probably eliminate shortfalls if defense budgets remain stable in real terms. Deeper reductions as outlined in

²¹FBIS, 1986.

²²Total Falkland expenditures total about £100 million. Curtis, 1987, p. 1; HM Treasury, 1989.

CFE II and III and a combination of efficiency gains and modest delays in the in-service dates of new equipment may eliminate shortfalls even if the defense budget decreases in real terms. However, CFE is very important in reducing equipment and personnel requirements and in the elimination of budget shortfalls.

Appendix A

EFFECTS OF COST GROWTH

Tables A.1, A.2, and A.3 illustrate the effects of 5 and 8 percent annual cost growth on Army, RAF, and RN major system production cost. Each table demonstrates a range of cost growth from 0 to 8 percent compounded from 1990 to expected system IOC. Systems already in production or slated for delivery in 1990 are assumed to have no cost growth. For various reasons, some other systems, such as Trident, are assumed to experience no or little cost growth despite their IOC date in the 1990s. The tables explicitly state these assumptions.

Table A.1
EFFECTS OF PRODUCTION COST GROWTH: ARMY EQUIPMENT
(Millions of £1987)^a

Equipment	IOC	Current Estimate	5% Annual Cost Growth	8% Annual Cost Growth
Light Attack Helicopter	1995	450	575	660
Trigat ^b	1996	300	400	475
Starstreak	1989	300	300	300
Rapier 2000/B2 ^c	1992	1850	2040	2160
Artillery ^d	1991 ^e	695	730	750
Leopard 2, M1A1, Challenger 2	1992	1400 ^f	1530 ^g	1610
Warrior/Saxon/FFLAV ^h	1988	1920	1740	1920
Warrior/Saxon/FFLAV ⁱ	1998	1100	1625	2035
FFLAV ^j	1997	270	380	465
FFLAV ^k	1997	200	280	345
Total		£8,485	£9780	£10,715

^aSome numbers are rounded.

^bIncludes long- and short-range systems.

^cIncludes RAF Rapier production costs.

^dIncludes Multiple Launch Rocket System (MLRS), ADP Bates, and 155 mm howitzer replacements.

^eWeighted average.

^fIncludes residual payment on current order of Challengers as outlined in Table 1.

^gCost growth excluded from current Challenger order.

^hCurrent production run to replace FV432.

ⁱLater production run to replace Ferret.

^jProduction run replacing Scorpion.

^kProduction run replacing Fox.

Table A.2
EFFECTS OF PRODUCTION COST GROWTH: RAF EQUIPMENT
(Millions of £1987)^a

Equipment	IOC	Current Estimate	5% Annual Cost Growth	8% Annual Cost Growth
Air defense				
Tornado F.3 ^b	1989	500	500	500
EFA	2000	3600	5865	7770
E-3 AWACs ^c	1991	790	790	790
M-SAM/other ^d	1995	1065	1360	1565
Rapier 2000 ^d	1993	1520	1760	1915
Tornado F.3 ^e	1994	295	295	295
Air defense sub-total		7770	10,570	12,835
Strike/attack				
EFA	1998	2400	3545	4440
Buccaneer replacement ^f	1995	915	915	915
Harrier GR.5	1988	300	300	300
Tornado GR.1 ^e	1994	505	505	505
Strike/attack sub-total		4120	5265	6160
Helicopter, Transport, and Other Assets				
EH-101 ^g	1998	280	415	520
EH-101 ^h	1991	245	255	265
EH-101 ⁱ	1992	200	220	235
EH-101 ^j	1992	90	100	105
EH-101 ^k	1998	95	140	175
VC10/Tristar/other transport	1998 ^m	75	110	140
C-130 replacement	1995	900	1150	1320
Miscellaneous transport	1997 ^m	100	140	170
Helicopter, transport, and other sub-total		1985	2530	2930
TOTAL		£13,875	£18,365	£21,930

^aSome numbers are rounded.

^bReplacing Phantom. Assumes no further cost growth.

^cFigures exclude Nimrod shut-down costs and assumes no cost growth due to fixed cost agreement.

^dPurchased for the RAF in the land procurement category.

^eAttrition purchase. Assumes no cost growth.

^fAssumes no cost growth since likely replacement (Tornado) is in production.

^gReplacing Chinook.

^hReplacing Puma transport.

ⁱReplacing Wessex transport.

^jReplacing Wessex SAR.

^kReplacing Sea King SAR.

^mAverage IOC.

Table A.3
EFFECTS OF PRODUCTION COST GROWTH: ROYAL NAVY EQUIPMENT
(Millions of £1987)^a

Equipment	IOC	Current Estimate	5% Annual Growth	8% Annual Growth
Fleet Air Arm	1997 ^b	850	1195	1455
Trident	1994	4500	5470 ^c	6120
Trafalgar SSN	1988	345	345 ^c	345
SSN 20	1998	2300	3400	4255
Upholder SSKs	1988	870	870	870
Assault ships	1995	200	255	295
Type 42, 82 replacement	1997	1800	2535	3085
Type 23 frigate	1989	1730	1730	1730
Type 22 frigate	1989	150	150	150
ASW frigate	2002	1500	2695	3775
Auxiliary oilers	1993	690	800	870
Aviation support	1993	135	155	170
Miscellaneous				
support, patrol	1997 ^d	200	280	345
MCMVs ^e	1991	400	420	430
TOTAL		£15,670	£20,300	£23,900

^aSome numbers are rounded.

^bWeighted average of replacement equipment.

^cBoth categories assume cost growth on Trident outlays since expenditure in the U.K. is subject to cost growth and that in the United States is subject to currency fluctuations.

^dAverage IOC.

^eMine countermeasures vessels.

Appendix B

GENERAL BUDGET EXPENDITURE FORECASTS

EDUCATION

About 75 percent of spending on education and science can be directly related to the number of students in public schools in the U.K. and to the costs per student. This analysis estimated future education expenditures based on estimated average costs per student and the number of students in six educational groups: under fives, primary, secondary, advanced further education (AFE), university, and those with government awards.

Several sources provided demographic and participation rate data for the number of students in each category.¹ Department of Education and Science (DES) estimates are used when available. DES data did not contain information on some student group participation rates beyond 1996, and participation rates are based on earlier DES data. For example, there was insufficient data to forecast precise numbers of Non-Advanced Further Education (NAFE) students, and these have been estimated these from Levitt and Joyce, 1984.

Table B.1 lists participation rates and the costs of education per student in £1987.² Table B.2 estimates the total number of students in 1991, 1996, 2000, and 2005. Projected Education and Science expenditures are found in the text in Table 6.

Table B.1
COSTS PER STUDENT AND PARTICIPATION RATES

Group (age)	£1987/Student	Group Participation Rate
Under 5 (0-4)	1132	10
Primary (5-10)	854	86
Secondary (11-17)	1191	59
AFE (18-25)	2716	4.2
University (18-25)	5458	4.6
Awards (18-25)	360	4.2

¹Department of Education, 1982 and 1984; Bureau of Population Statistics, 1988.

²Participation rates for university students may be understated. Recent DES reports expect an increase of 30 percent in university participation rates in the 1990s. See *The Economist*, 1987. Cost estimates do not reflect the large real increases in education costs in the U.K. since 1980 and may understate future costs. Costs have recently increased at a real rate of 3.8 percent per year (*The Government's Expenditure Plans 1988-89 to 1990-91*, 1988, p. 17).

Table B.2
FUTURE STUDENT NUMBERS
(Thousands)

Group	1991	1996	2000	2005
Under Five	345	360	400	367
Primary	3702	4053	4223	4140
Secondary	2779	3047	3080	3329
AFE	245	227	235	247
University	343	310	254	268
Awards	245	227	235	247

SOCIAL SECURITY

The model described in the text forecasts future British social security expenditures. The U.K. social security system is terribly complex (as is the U.S. system) and a close examination of future expenditures is not feasible. However, projections based on demographic data provide some insight into future expenditures.

U.K. social security expenditures is best broken down into contributory benefits (primarily pension payments), noncontributory payments (primarily income supplements and family and child benefits), and administrative costs.

Contributory Benefits

Contributory benefits include pensions, widows' benefits, some unemployment benefits, industrial injury benefits, and a very small amount of family benefits. Pensions account for roughly 75 percent of all contributory benefits; thus, the number of pensioners and increases in pension benefits should provide a rough approximation of future contributory benefit expenditures.

Pension benefits are available in Britain to qualified men 65 years and older and to qualified women 60 years and older. A potential recipient must have contributed to the pension fund to qualify. The ratio of those eligible in 1990 is assumed to remain constant through 2005. This probably underestimates total eligible recipients since a greater percentage of women work today and will in the future be eligible for benefits.³

Bureau of Population Statistics data indicate a stable retired population to the year 2005. In fact, these data, as well as World Bank Population projections,⁴ indicate that the ratio of the retired to the working population (important to keep the pension fund in balance without additional revenues) in the U.K. will *fall* slightly between 1990 and 2005 before increasing. It will remain at about 28 percent to 2010 and is expected to increase to 35 percent in about 2025.

³However, if more women are eligible, more will pay into the fund as well.

⁴Vu, 1984.

Aggregate contributory benefits are assumed to increase according to the number of pensioners and at a real annual rate of 1.5 percent. This is slightly less than historically observed rates since 1971 of about 1.9 percent per year.⁵

Noncontributory Benefits

Noncontributory benefits include war pensions, disability benefits, income support/social fund, and family and housing benefits. Roughly two-thirds of noncontributory benefits are a function of the number of children in a household; thus, changes in the number of children in the U.K. and anticipated average increases in benefits should provide a useful surrogate measure of noncontributory expenditure growth. Calculations are based on the number of children to age 14. These calculations may be biased because already evident social trends are not taken into consideration. For example, single parent families are assumed to remain a constant percentage of all families, although recent evidence indicates an increase. Other recent changes in means tested benefits (MTB) may, however, point to an upward bias. Decreases in the number of those eligible for MTB may lead to decreases in noncontributory spending.⁶

Assumed real increases in noncontributory benefits of 1.5 percent per year are slightly higher than recent trends.⁷

Administrative Costs

The model estimates that administrative costs remain about 4 percent of total expenditures. Table B.3 forecasts social security expenditures in roughly five-year intervals to 2005.

Table B.3
PROJECTED SOCIAL SECURITY EXPENDITURES TO 2005
(Millions of £1987)

	1988	1995	2000	2005
Contributory	25,600	28,480	30,050	33,800
Noncontributory	20,165	24,220	26,940	28,560
Administrative	2,100	2,195	2,410	2,640
Total	47,865	54,900	60,200	65,000
Average annual change (percent)	—	2.0	1.9	1.5

⁵See Social Security Statistics 1987, 1987, p. 85.

⁶See Levitt and Joyce, 1984, pp. 4,5, 26-27. In particular, Housing and Supplementary Benefits may be reduced.

⁷See Social Security Statistics 1987, 1987, pp. 62, 162, 167. For example, individual child benefits have increased at just over 1 percent per year, Guardian's Allowance has decreased slightly in real terms, Family Income Supplement has remained flat in real terms.

HEALTH AND PERSONAL SOCIAL SERVICES

Forecasts for future health and personal social services are based on expected real increases in health and personal social service costs and demographic changes.

Demographic data were obtained from the Bureau of Population Statistics. The costs of individual future health care are assumed to increase in real terms at 2.5 percent per year. This is comparable to recent real growth in the Health and Personal Social Services portion of general government expenditures.⁸ This ignores possible efficiency gains and losses, such as unexpected cost increases from additional family practitioner services and other areas of likely benefit growth. Initial costs of care on an age-related basis were derived from Department of Health and Social Services statistics.⁹ Table B.4 illustrates social security expenditure forecasts using 1988 expenditure as a baseline.

Table B.4
HEALTH AND SOCIAL SERVICE COST PROJECTIONS
(Millions of £1987)

	1988	1995	2000	2005
Total	24,503	30,672	34,664	39,747
Average annual change (percent)	—	3.3	2.5	2.8

⁸See *The Government's Expenditure Plans 1988-89 to 1990-91*, 1988, p. 40.

⁹Cited in Levitt and Joyce, 1984, pp. 22-23.

Appendix C

HISTORICAL BUDGET DATA

This appendix contains historical British defense budget data from 1971 to 1989.¹ Unless otherwise indicated, figures are based upon actual spending reported in *The Supply Estimates*; therefore, they may not always correspond with data found in the yearly *Statement on the Defence Estimates*.

There are numerous gaps in the data resulting from changes in methods and details of reporting. For example, maintenance expenditure has only recently been reported. (Support data may have contained some or all of these expenditures, although this is unclear.) As a specific example, "Land Procurement" lists maintenance spending only in later years. Zero designates no expenditure reported.

Table C.1 is fairly straightforward. All figures express net expenditures unless otherwise indicated; and 1971, 1973, and 1974 totals are estimated from U.S. Department of Defense figures.

In some cases, no breakdown of air development was provided. In those instances, air weapons, avionics, and electronic equipment are included in aircraft development. Land communications equipment, guided weapons, and surveillance equipment are combined in some cases. Aid denotes military assistance to third parties.

¹I have expressed defense budget data in fiscal year terms. For example, 1971 describes 1971/2.

Table C.1

HISTORICAL BUDGET DATA (Net, thousands of current £)

Year	71/2	72/3	73/4	74/5	75/6	76/7	77/8	78/9	79/80	80/81
Defense Spending										
	3013625	3324200	3463100	4648425	5775875	6158000	6787000	7455000	9178000	11182000
Personnel										
Gross Personnel	1304062	1434881	1461179	1841684	2287192	2601067	2751744	2987817	3604429	4223859
Net Personnel	1272198	1401145	1427840	1792889	2223285	2531225	2669846	2882449	3480125	4074979
Gross Active Personnel	1164642	859919	854290	1065981	1344364	1518600	1591078	1710896	2183736	2579277
Net Active Personnel	1133298	1247026	1254370	1504860	1962478	2213354	2305242	2451573	3009564	3574648
Gross RN Personnel	171659	191060	189560	234859	299228	329711	347517	381571	491888	590787
RN Personnel Aid	2025	2380	2610	2515	3369	4150	5004	5971	6325	7930
Net RN Personnel	169634	189680	186950	232344	295859	325561	342513	375800	485563	572857
Gross Army Personnel	349570	402300	403810	520271	664879	784299	826285	874520	1092138	1280688
Army Personnel Aid	19284	20670	19420	26417	30855	30772	43147	59483	68233	85770
Net Army Personnel	330286	381630	384390	493854	634024	753527	783138	815037	1023905	1194918
Gross RAF personnel	238286	265559	260920	310851	380257	404590	417276	454805	599710	717802
RAF Personnel Aid	2694	2985	2990	3889	6638	7493	7521	9080	10850	13085
Net RAF Personnel	235592	263574	257830	306962	373619	397097	409755	445725	588860	704717
Gross Civilian Personnel	405127	420292	432859	573900	676374	758585	790690	840837	944530	1141854
Civilian Personnel Aid	7341	7150	7759	12200	17398	21416	20854	25626	33294	39698
Net Civilian Personnel	397786	413142	425100	561700	659976	737169	769636	815211	911236	1102156
Gross Retired Pay	139420	154670	174030	201803	266454	323882	369976	438084	476163	502828
Retired Pay Aid	520	550	560	3774	5647	6011	5372	6208	5602	2497
Net Retired Pay	138900	154120	173470	198029	260807	317871	364604	430876	470561	500331
Procurement										
Gross Procurement	1182285	1342876	1482094	1722258	2224781	2716735	3183712	3703525	4256946	5701222
Net Procurement	942632	1146376	1287314	1482144	2012664	2339642	2756921	3205613	3935935	5072834
Gross Other Procurement	27571	209107	261202	301351	430202	502023	558419	590955	718630	817063
Net Other Procurement	-62168	203695	255128	275386	493776	444771	498339	532421	643366	732619
Gross Sea Procurement	195979	266535	314219	342570	450412	590327	718166	854501	1075433	1499949
Net Sea Procurement	179582	246866	290505	320005	398737	530977	644225	777181	990380	1363346
Development	24214	29827	32340	39480	62060	67482	78007	117816	194790	263781
Development Aid	330	305	400	300	650	930	1005	1006	1310	1625
Net Development	23884	29522	31940	39180	61410	66562	78002	116810	193480	282156

Year	71/2	72/3	73/4	74/5	75/6	76/7	77/8	78/9	79/80	80/81
Gross Sea Production	171765	236708	281879	303090	388352	522845	639159	736685	880643	1216168
of which:										
Hulls	53494	74809	103033	97139	135085	194467	237034	265369	332320	422034
Weapons	62959	88858	10826	128303	143798	157414	208660	261829	300720	443687
Support	55312	72558	78007	77648	109469	46311	53569	59468	60753	92115
Maintenance	0	0	0	0	0	124653	139896	150019	186850	258332
Whole Ship/Other	0	483	13	0	0	0	0	0	0	0
Production Aid	16067	19364	23314	22265	51025	58420	72936	76314	83743	104978
Net Production	155698	217344	258555	280825	337327	464425	566223	660371	796900	1111180
Gross Land Procurement	154182	203520	266654	361766	491334	637202	765501	903650	882024	1138302
Net Land Procurement	106682	141720	172000	274266	387334	483201	618301	696290	876924	903239
Development	11700	12030	13787	41000	48000	58807	66200	76350	113000	188489
Development Aid	700	1600	431	2100	5000	6000	7200	4600	5100	6853
Net Development	11000	10430	13356	38900	43000	52807	59000	74750	107900	181636
Production	142482	191490	252867	320766	443334	578395	699301	824300	769024	949813
of which:										
Guns, Small Arms	6700	8620	12578	12700	19773	32500	41100	44000	59000	63104
Ammunition	52000	67480	74605	55000	96464	145000	237452	220000	197024	211667
Fighting Vehicles	30100	41450	64178	67000	70000	80000	69000	182000	100000	92860
Load-carrying Vehicles	28398	35820	50967	46200	78000	96000	91222	97000	120000	177404
Engineering	18600	20270	24403	23490	27000	38000	41900	40000	41000	53719
Guided Weapons	0	0	0	96536	140097	163031	190027	215000	253000	310036
Communications	0	0	0	0	0	0	0	0	0	0
Surveillance	0	0	0	0	0	0	0	0	0	0
Other	6684	17860	26136	19840	22000	23864	28600	26300	0	41023
Maintenance	0	0	0	0	0	0	0	0	0	0
Production Aid	48900	60200	94223	85400	99000	148001	140000	212760	0	228210
Net Production	96682	131290	158644	235366	344334	430394	559301	611540	769024	721603
Gross Air Procurement	540013	663714	640019	716571	862833	987183	1151626	1364419	1590859	2245908
Net Air Procurement	470390	554095	596681	612507	732817	880593	996056	1209721	1425265	2043630
Gross Development	125048	174766	120546	161286	229197	274521	314366	344906	403367	531200
of which:										
Aircraft	66862	0	0	0	0	0	0	0	0	0
Weapons, Electronics	63256	0	0	0	0	0	0	0	0	0
Development Aid	3739	16558	13328	7935	13945	16084	20571	26831	34138	47300
Net Development	121309	156208	107218	153351	215252	258437	293795	318075	369229	483900

Year	71/2	72/3	73/4	74/5	75/6	76/7	77/8	78/9	79/80	80/81
Gross Air Production of which:	414965	489048	519473	555285	623636	712662	837260	1019513	1177492	1714708
Aircraft	307220	361608	351713	475262	539380	592372	698275	819924	943468	1346560
Helicopters	0	0	0	0	0	0	0	0	0	0
Avionics	0	0	0	80023	84256	120290	148985	199599	234024	368148
Guided Weapons	107745	127340	167760	0	0	0	0	0	0	0
Electronics	0	0	0	0	0	0	0	0	0	0
Support	0	0	0	0	0	0	0	0	0	0
Production Aid	65884	93061	57010	96129	106071	90506	134999	127867	121456	154978
Net Production	349081	395987	462463	459156	517565	622156	702261	891646	1056036	1559730
Operations	798795	776678	747946	1373392	1539926	1287233	1360233	1366938	1761940	2034187
Net Movements	64470	68320	70100	84060	106558	128062	143639	166820	194145	232414
Aid	3545	2630	3240	4740	6387	5455	5836	8322	12583	8387
Net Movement	60925	65690	66960	79320	100171	122597	137803	158498	181552	224027
Gross Miscellaneous Stores	18840	42390	51800	53792	74080	88066	85643	92119	128581	144205
Aid	2290	4085	3890	1472	4041	5077	5663	7942	8649	9559
Net Miscellaneous Stores	16550	38305	47910	52320	70039	82989	79980	84177	119932	134646
Gross Clothing	20600	59950	62990	88450	120883	122133	141431	143594	176867	194330
Aid	1506	23780	23000	30468	36304	43583	49062	57125	60167	71221
Net Clothing	19096	36170	39990	57982	84579	78550	92369	86469	116700	123109
Gross Fuel, Utilities	101325	97960	96300	221660	269907	305658	349197	333341	480080	554638
Aid	9820	13825	14405	23420	32008	36618	45282	47217	52212	67621
Net Fuel, Utilities	91506	84135	80895	198240	237899	269040	303915	286124	427868	487017
Other	402005	552378	512291	985530	1047238	734057	746166	751670	915888	1065388

Year		81/2	82/3	83/4	84/5	85/6	86/7	87/8	88/9	89/90
Defense Spending		12607000	14412000	15487000	17122000	17983334	18771786	18785744	19221273	20148714
Personnel										
Gross Personnel		4663320	5019602	5339667	5629097	6083434	6573439	6901167	7402124	7941482
Net Personnel		4454099	4830134	5104951	5372159	5821871	6300468	6612620	7115570	7664800
Gross Active Personnel		2896285	3063385	3250854	3432296	3710142	3979120	4154189	4494823	4777834
Net Active Personnel		3832431	4149760	4327956	4544421	4923830	5325924	5563926	6014054	6462079
Gross RN Personnel		655553	686351	729638	757206	811746	844164	889354	939258	1014232
RN Personnel Aid		9089	10745	11163	10477	11401	10771	13614	13478	8488
Net RN Personnel		646464	675606	718475	746729	800345	833393	875740	925780	1005744
Gross Army Personnel		1432827	1520797	1610672	1697602	1824862	1982434	2038209	2235448	2345604
Army Personnel Aid		144121	114473	145124	168310	168719	170146	175724	170224	159172
Net Army Personnel		1288706	1406324	1465548	1529292	1656143	1812288	1862485	2065224	2186432
Gross RAF personnel		806905	846237	910544	977488	1073534	1152522	1226626	1320117	1417998
RAF Personnel Aid		14085	15487	19821	18420	20156	24298	23250	22681	25548
Net RAF Personnel		792820	830750	890723	959068	1053378	1128224	1203376	1297436	1392450
Gross Civilian Personnel		1144205	1283913	1309922	1367380	1474174	1618619	1697125	1804661	1959578
Civilian Personnel Aid		39764	46833	56712	58048	60210	66600	74900	79047	82125
Net Civilian Personnel		1104441	1237080	1253210	1309332	1413964	1552019	1622225	1725614	1877453
Gross Retired Pay		623830	682304	778891	829421	899118	975700	1049853	1102640	1204070
Retired Pay Aid		2162	1930	1896	1683	1077	1156	1059	1124	1349
Net Retired Pay		621668	680374	776995	827738	898041	974544	1048784	1101516	1202721
Procurement										
Gross Procurement		6532819	7142893	7796280	8709489	8985181	9211756	9015572	8572683	8906122
Net Procurement		5782267	6484439	7133634	8098408	8355251	8666473	8431511	8004810	8343668
Gross Other Procurement		875530	951962	975438	1078315	1084967	1115950	1189277	1361511	1488596
Net Other Procurement		771214	882148	850984	970542	938677	1014508	1081999	1204075	1311694
Gross Sea Procurement		1621031	1739536	1892640	2220905	2456978	2596270	2670220	2551876	2471132
Net Sea Procurement		1496353	1608872	1751412	2087596	2320494	2432804	2490700	2375782	2303176
Development		280014	263774	362072	441015	510339	492924	502492	459852	382994
Development Aid		1054	1716	2403	1662	1738	2381	2262	4244	7137
Net Development		279860	262058	359669	439353	508601	490543	500230	455608	375857

Year	81/2	82/3	83/4	84/5	85/6	86/7	87/8	88/9	89/90
Gross Sea Production	1341017	1475762	1530568	1778990	1946639	2103346	2167728	2092024	2088138
of which:									
Hulls	518825	499260	497431	555435	567315	563052	597039	551185	578440
Weapons	480518	554989	591421	726584	784122	924531	894637	779703	681592
Support	87260	91729	91711	91048	128673	126118	144404	153612	164793
Maintenance	254414	323534	343755	400573	458150	480912	498077	549772	587952
Whole Ship/Other	0	6250	6250	6250	8379	8733	33571	57752	75361
Production Aid	123624	128948	138825	131648	134746	161085	177258	171850	160819
Net Production	1217393	1346814	1391743	1648242	1811893	1942261	1990470	1920174	1927319
Gross Land Procurement	1306801	1653199	1642858	1842035	1967729	1890158	1792058	1750023	1738148
Net Land Procurement	1057149	1353454	1475028	1637468	1864310	1771902	1690331	1669558	1678928
Development	246553	220384	244395	269012	269012	319693	296417	314193	308580
Development Aid	10663	8920	15156	10651	10651	16386	22192	16198	9933
Net Development	235990	211464	229239	258361	258361	303297	274225	297995	298647
Production	1060248	1432815	1398463	1573023	1698717	1560465	1495641	1435830	1429568
of which:									
Guns, Small Arms	67471	49497	30901	27907	23186	39080	64512	79123	102655
Ammunition	250928	286752	278493	322405	302235	271595	243236	198015	198373
Fighting Vehicles	124423	99569	116737	131467	154740	149660	187817	246598	178990
Load-carrying Vehicles	143654	134270	118947	156074	167432	148060	162898	138470	100365
Engineering	45118	88440	82770	88595	84816	59710	53141	40594	37274
Guided Weapons	420913	581898	578583	234775	244665	229230	206207	182725	203732
Communications	0	0	0	258885	269758	233070	191158	168156	148465
Surveillance	0	0	0	108358	112922	90820	79701	70504	106571
Other	7741	32805	34361	29234	6218	8080	8279	9849	4491
Maintenance	0	159594	156671	215323	332745	331250	298592	301796	359652
Production Aid	238989	290825	152674	193916	92768	91860	79535	64267	49287
Net Production	821259	1141990	1245789	1379107	1605949	1468605	1416106	1371563	1380281
Gross Air Procurement	2729457	2798196	3285344	3567234	3385607	3619478	3364017	2908273	3208246
Net Air Procurement	2457551	2639965	3056210	3402803	3231770	3447259	3168481	2755395	3049870
Gross Development	562341	493510	603804	624309	677279	711124	804204	644618	692990
of which:									
Aircraft	348683	304248	354159	358228	398340	474989	492172	366554	405303
Weapons, Electronics	213658	189262	249645	266081	278939	236135	312032	278064	277687
Development Aid	49331	32872	33336	41836	67818	82197	62832	49758	39600
Net Development	513010	460638	570468	582473	609461	628927	741372	594860	643390

Year	81/2	82/3	83/4	84/5	85/6	86/7	87/8	88/9	89/90
Gross Air Production	2167116	2304686	2681540	2942925	2708328	2908354	2559813	2264655	2525256
of which:									
Aircraft	1653909	1698079	1728946	940712	832184	924659	655973	524761	658210
Helicopters	0	0	0	30044	28704	46840	35288	49177	69170
Avionics	513207	605607	961594	280407	277239	332915	385174	355338	572124
Guided Weapons	0	0	0	370638	366352	331233	298523	244763	167022
Electronics	0	0	0	320466	317545	366570	382800	447534	425191
Support	0	0	0	1000758	885304	914137	801055	643082	633539
Production Aid	222575	125359	195798	122595	86019	90022	132704	104120	118776
Net Production	1944541	2179327	2485742	2820330	2622309	2818332	2427109	2160836	2406480
Operations	2370634	3097427	3248415	3651433	3816212	3804845	3741613	4100893	4140246
Net Movements	218314	357536	329127	355746	282776	368779	352860	372385	402285
Aid	9786	10254	9884	13037	73805	16491	12363	12536	12004
Net Movement	208529	347282	319243	342709	208971	352288	340507	359849	390281
Gross Miscellaneous Stores	158742	143057	258665	290639	332693	352288	335063	387842	440597
Aid	8492	8782	10343	12310	294930	330374	13147	13824	15427
Net Miscellaneous Stores	150250	134275	248322	278329	37783	21914	321916	374018	425170
Gross Clothing	181188	211354	215850	253819	88485	271199	280151	272664	258512
Aid	83217	79426	84628	89608	101523	98282	103775	163606	116016
Net Clothing	97971	131928	131222	164211	-13038	172917	176376	109068	142496
Gross Fuel, Utilities	637775	982071	817069	893414	797163	615010	578863	604561	577718
Aid	91458	87426	105838	105073	110389	90572	86697	83225	98742
Net Fuel, Utilities	546317	894645	711231	788341	686774	524438	492156	521336	478976
Other	1366567	1589297	1838397	2077843	2896742	2733288	2410658	2736632	2703323

Appendix D

ACCOUNTING ADJUSTMENTS

Several minor accounting adjustments are necessary to reconcile differences between service and geographic procurement categories as reported in official British sources. These result in decreases in major production requirements.

British accounting practices and the budget model designate land, air, and sea equipment categories. These correspond roughly with Army, RAF, and Royal Navy procurement, with two notable exceptions. First, the air procurement category includes all Army and Royal Navy aircraft. Requirements for these items, listed in Tables 1 (£450 million) and 3 (£850 million), would normally be included in air equipment requirements. However, since projected Army and Royal Navy aircraft are excluded from the model's estimate of future air procurement, these requirements are omitted. This eliminates any possible double counting and results in a reduction of total air equipment requirements.

Second, the land procurement category includes all RAF air defense surface-to-air missile requirements and resources. Requirements for RAF Rapier B2/2000 (£1520 million) would normally be transferred to this category; however, because there is uncertainty regarding the total costs of Army and RAF Rapier upgrades and to avoid possible double counting, only requirements (£1850 million) for Army Rapier SAMs are included in land requirements, resulting in a decrease in land requirements.

Finally, it is unclear whether the "Guns and Small Arms" land procurement category includes all artillery requirements. This seems unlikely given the small expenditures in this category. However, to avoid the possibility of double counting MLRS and other artillery requirements, I have excluded artillery requirements in land equipment totals. Including artillery modernization costs would have a negligible effect on the model outcome.¹

¹It would increase the Army's total shortfall £695 million over 15 years in all scenarios.

Appendix E

THE DEFENSE BUDGET MODEL

MODEL STRUCTURE AND MAJOR EQUIPMENT PRODUCTION SHORTFALLS

A residual defense budget model was used to estimate resources for the production of major equipment. Estimated expenditures for all non-major equipment production are subtracted from a forecast range of aggregate defense budgets from 1990 to 2005. The residual represents available resources for the production of major equipment. These resources are compared with a range of estimated major equipment production requirements to determine major equipment production shortfalls.

DEFENSE BUDGET SHORTFALLS

The middle-case major equipment production shortfall of £22.5 billion represents the difference between major equipment production resources and requirements. This understates additional increases in aggregate defense spending necessary to eliminate variable expenditure categories (maintenance, development, minor equipment production, and operations) in the budget model. Increases in aggregate defense spending do not translate into equal increases in major equipment production resources. For example, a £1 billion increase in aggregate defense spending translates into a less than £1 billion (about £224 million) increase in major equipment production resources. Defense budget shortfalls described in the text represent aggregate defense budget increases necessary to eliminate major equipment shortfalls and to pay for all variable operations expenditures.

This estimation of defense budget shortfalls includes required increases for all variable expenditure categories (operations, development, maintenance, and minor equipment) and may overestimate defense budget shortfalls. For example, although maintenance and operations appear directly related to major production expenditures, in theory at least, it is less clear that development and minor equipment expenditures are related to major production expenditures. This, however, is not reflected in historical data we have used to construct the budget model.

Aggregate defense budget shortfalls are calculated by substituting variables in the budget model to determine the relationship between major equipment resources M ($L_r + A_r + S_r$) and the aggregate defense budget, B . Substitution gives $M = .224 \times B - \text{exogenous expenditures}$. (In the middle case, exogenous expenditures equal £50,410 million.) $\partial M / \partial B$ equals .224; to eliminate a £1 billion equipment production shortfall, B must increase by $1/.224$, or £4.46 billion. Aggregate defense budget shortfalls are therefore about four and one-half times greater than major equipment production shortfalls.

BIBLIOGRAPHY

- Air Pictorial*, "British go-ahead for EFA," June 1988a, p. 206.
- Air Pictorial*, World Air News," June 1987, p. 210.
- Air Pictorial*, World Air News," June 1988a, p. 206.
- Air Pictorial*, World Air News," July 1988b, p. 247.
- Allward, Maurice, *Buccaneer*, Ian Allan, Ltd., London, 1981.
- Aviation Advisory Service, *Milavnews*, NL-208/2/79, 1979, pp. 13-14.
- Aviation Advisory Service, *Milavnews*, NL-252/10/82, 1982, p. 18.
- Aviation Advisory Service, *Milavnews*, Vol 22, NL-255/1/83, 1983, p. 17.
- Aviation Advisory Service, *Milavnews*, Vol. 23, NL-277/11/84, 1984, p. 11.
- Aviation Advisory Service, *Milavnews*, Vol. 24, NL-279/1/85, 1985.
- Aviation Advisory Service, *Milavnews*, Vol. 26, NL-313/11/87, 1987, p. 10.
- Aviation Advisory Service, *Milavnews*, Vol. 27, NL-316/2/88, 1988, p. 13.
- Aviation Advisory Service, *Milavnews*, Vol 28, NL-328/2/89, 1989a, p. 11.
- Aviation Advisory Service, *Milavnews*, Vol 28, NL-332/6/89, 1989b, p. 10.
- Aviation Week and Space Technology*, "British Labor Party Modifies Stance on Nuclear Disarmament," May 15, 1989, p. 29.
- Beaver, Paul, *Encyclopaedia of the Modern Royal Navy*, Naval Institute Press, Annapolis, 1982.
- Beyers, Dan, "U.S. Government and Industry Creating Stiff Competition for Europeans," *Defense News*, January 4, 1988, p. 6.
- Brown, David A., "British Seek Risk-Sharing Partners for High-Agility Aircraft Project," *Aviation Week and Space Technology*, December 14, 1987.
- Bureau of Population Statistics, unpublished population projections by the U.K. Government Actuary, 1988.
- Burns, Michael, *Phantom II*, Osprey Publishing Limited, London, 1984.

The Central Organization for Defence, Cmnd. 9315, HMSO, London, 1985.

Chalmers, Malcolm, *The 1987 Defence Budget: Time for Choice?* Peace Research Report #17, University of Bradford, School of Peace Studies, 1987.

Chartres, John, *Avro Shackleton*, Ian Allan, Ltd., London, 1985.

Coker, Chris, *A Nation in Retreat*, Brassey's Defence Publishers, London, 1986.

Cook, Nick, "W Germany, UK and Italy set to order more Tornados," *Jane's Defence Weekly*, February 13, 1988, p. 245.

Cook, Nick, "UKs Bloodhound successor: BAe in MSAM studies," *Jane's Defence Weekly*, March 26, 1988, p. 551.

Coxhead, C.D., "Pressure for Change in Military Aviation," *Air Clues*, April 1987.

Curtis, Ian, "Britain's Conservative Conference: Next Trident to Vickers; More Type 23s," *Defense and Foreign Affairs Daily*, October 9, 1987, p. 2.

Curtis, Ian, "UK Defence Committee Releases Report on Falkland Island Today," *Defense and Foreign Affairs Daily*, Vol. XVI, No. 129, July 9, 1987, p. 1.

Daly, Mark, "The threat facing the UK main battle tank industry," *Jane's Defence Weekly*, July 2, 1988, pp. 1764-1765.

Dean, Jonathan, "Conventional Talks: A Good First Round," *The Bulletin of the Atomic Scientists*, October 1989, pp. 26-31.

De Briganti, Giovanni and Theresa Hitchens, "NATO Frigate Project Sinks Under Withdrawals," *Defense News*, Vol. 4, No. 41, October 9, 1989, pp. 1, 66.

Defence Without the Bomb: A Report of the Alternative Defence Commission, Taylor and Francis, New York, 1983.

Defense and Economy World Report, No. 1036, March 2, 1987.

Defense Marketing Service, *Market Intelligence Reports*, 1989, Defense Marketing Service, Greenwich, Connecticut, 1989.

Degenhardt, Henry D., *Treaties and Alliances of the World* (4th ed.), Gale Research Company, Detroit, 1986.

Department of Education, *Demand for higher education in Great Britain 1984-2000*, DES Report No. 100, July 1984.

Department of Education, *Pupils and school leavers: Future numbers*, DES Report No. 97, May 1982.

Department of Employment, *New Earnings Surveys*, Government Statistical Office, London, 1971-1987.

Dews, E., G. K. Smith, A. A. Barbour, E. D. Harris, M. A. Hesse, *Acquisition Policy Effectiveness: Department of Defense Experience in the 1970s*, The RAND Corporation, R-2516-DR&E, October 1979.

Don, Bruce, "Allies and Adversaries: Policy Insights Into Strategic Defense Relationships," The RAND Corporation, P-7242, 1986.

Dunn, Ralph, "RN planning for 20 Type 23 frigates," *Jane's Defence Weekly*, Sept. 5, 1987.

The Economist, "Higher Education in Europe," July 11, 1987, pp. 19-21.

The Economist, "Nott's Question Remains," May 21, 1988a, pp. 64-65.

The Economist, "The old country," May 28, 1988b.

"A workforce facing middle-aged spread," *The Economist*, August 6, 1988c, pp. 43-44.

Evans, Michael, "2bn pound take-off for new fighter," *The Times* (London), November 7, 1987.

Fairhall, David, "Europe Wary of American Nuclear Stance," *Manchester Guardian*, February 22, 1987, p. 4.

Finnegan, Philip, "Tight Budgets May Delay U.S.-U.K. Experimental Fighter Plane," *Defense News*, September 11, 1989, p. 54.

Foreign Broadcast Information Service (FBIS), *Western Europe*, September 10, 1986, p. Q1.

Forecast Associates, *Aircraft Forecast*, Forecast Associates, Newtown, Connecticut, 1989.

Foss, Christopher F., "UK launches 7000 vehicle FFLAV project," *Jane's Defence Weekly*, April 8, 1989, p. 584.

Garner, Richard, "Teacher Shortage Confounds British Reform Effort," *International Herald Tribune*, February 18-19, 1989, p. 12.

George, Bruce, "Royal Navy Faces Dangerous Future," *Defense News*, August 1, 1988, p. 53.

The Government's Expenditure Plans 1988-89 to 1990-91, Cmnd. 288-I, HMSO, London, 1988.

The Government's Expenditure Plans 1989-90 to 1991-92, Cmnd. 621, HMSO, London, 1989.

Greenwood, David, "Memorandum # 11" in House of Commons Defense Committee, *Defence Commitments and Resources and The Defence Estimates 1985-86*, HC 37-II, (1984-85 Session), HMSO, London, 1985.

Greenwood, David, and David Hazel, "The Evolution of Britain's Defence Priorities 1957-76," *Aberdeen Studies in Defence Economics*, No. 9, September 1977.

Hartley, Keith, *NATO Arms Co-operation: A Study in Economics and Politics*, Allen & Unwin, Boston, 1983.

Hatch, Paul, "The Royal Air Force Today," *Air Pictorial*, Vol. 49, No. 9, September 1987, pp. 337-346.

HM Treasury, *Autumn Statement*, November 1988.

HM Treasury, *The Government's Expenditure Plans 1989-90 to 1991-92, Chapter 1, Ministry of Defence*, Cmnd. 601, January 1989, pp. 4-5.

Hooten, Ted, "NFR-90: NATO's next-generation frigate?" *International Defense Review*, April 19, 1988, pp. 409-411.

House of Commons Defence Committee, *Defence Commitments and Resources and the Defence Estimates 1985-86*, H.C. 37-II, HMSO, London, 1985.

House of Commons, *Third Report from the Defence Committee, "The Progress of the Trident Programme,"* Session 1986-87, HMSO, London, 1987.

International Institute for Strategic Studies, *The Military Balance 1989*, IISS, London, 1988.

Jackson, Paul, "Lament for the Lightning," *Air International*, June, 1988, pp. 279-289, 307.

Jackson, Peter, and Francis Terry, *Public Domain*, Public Finance Foundation, London, 1987.

Jane's All the World's Aircraft, Jane's Publishing Company, London, 1988.

Jane's Armour and Artillery, Jane's Publishing Company, London, 1988.

Jane's Defence Weekly, "Abrams 'made in UK' offer to VSEL," June 18, 1988a, p. 1195.

_____ "British Army's dilemma over 'outdated' howitzers," February 20, 1988b, p. 289.

_____ "Challenger 2 decision," February 27, 1988c, p. 349.

_____ "50% of UK budget going on excess costs," March 19, 1988d, p. 493.

_____ "News in Brief," May 21, 1988e, p. 1000.

_____ "NFR-90 agreement releases new funds," May 14, 1988f, p. 929.

_____ "Second AOR to be built for Royal Navy," January 16, 1988g, p. 54.

_____ "UK embarks on FFLAV programme," August 1, 1987, pp. 164-165.

- _____ "UK finally joins Trigat programme," May 7, 1988h, p. 871.
- Jane's Fighting Ships*, Jane's Publishing Company, New York, 1988.
- Jane's NATO Report*, "UK Considers R&D," September 12, 1988, p. 6.
- Jane's Weapon Systems*, Jane's Publishing Company, New York, 1988.
- International Monetary Fund, *International Financial Statistics*, IMF, New York, 1988.
- Kemp, Ian, "UK stalls on 'difficult decisions'," *Jane's Defence Weekly*, May 28, 1988, p. 1057.
- Kinnock, Neil, "How Labour Would Defend Britain," *New York Times*, March 27, 1987.
- Levitt, M.S., and M.A.S. Joyce, *Public Expenditures: The Next Ten Years*, Discussion Paper #76, National Institute of Economic and Social Research, London, 1984.
- Lewis, Kevin N., "What if the Reagan Defense Buildup Is Over?" The RAND Corporation, P-7347, April 1987.
- Mason, Francis K., *Harrier*, 2d ed., Naval Institute Press, Annapolis, 1983.
- Military Almanac," *Military Technology*, January annual issue.
- Miller, Charles, "Britain Plans to Maintain Its Own Nuclear Deterrent," *Defense News*, August 21, 1989a, p. 41.
- Miller, Charles, "Labour Party Isolates Its Left Wing on Defense Issues," *Defense News*, May 22, 1989b, p. 4.
- Miller, Charles, "RAF to Modernize Chinooks," *Defense News*, October 23, 1989c, p. 34.
- Miller, Charles, "U.K. Labor Party Rethinks Its Disarmament Stance," *Defense News*, February 13, 1989d, p. 3.
- National Audit Office, *Ministry of Defence and Property Services Agency: Control and Management of the Trident Programme*, HC-27, HMSO, London, 1987.
- NATO Report*, "British Labour Party Reviewing Defence Policies," Vol. 3, No. 33, May 27, 1988a.
- NATO Report*, "Political Shifts in NATO Members Could Affect Policy," Vol. 3, No. 31, May 13, 1988b.
- Perry, R.L., G. K. Smith, A. J. Harman, and S. Henrichsen, *System Acquisition Strategies*, The RAND Corporation, R-733-PR/ARPA, June 1971.
- Politi, Alessandro, "European Fighter Aircraft to Feature Stealth Technologies, Italy Minister Says," *Defense News*, May 23, 1988, p. 6.

Pugh, Philip, *The Costs of Sea Power*, Conway, London, 1986.

Pugh, Philip, and D.L. Kirkpatrick, "Towards the Starship Enterprise: Are the Current Trends in Defence Unit Costs Inexorable?" cited in C.D. Coxhead, "Pressure for Change in Military Aviation," *Air Clues*, April 1987, pp. 123-124.

Riddell, Peter, "UK to join warship project," *Financial Times*, January 20, 1988.

Sandler, Todd, and James C. Murdoch, "Defense Burdens and Prospects for the Northern Allies," in David B.H. Denoon, *Constraints on Strategy: The Economics of Western Security*, Pergamon-Brassey's, New York, 1986, pp. 59-113.

Smith, J. P., and F. Welch, "No Time to be Young: The Economic Prospects for Large Cohorts in the United States," *Population and Development Review*, 7 March 1981.

Social Security Statistics 1987, HMSO, London, 1987.

Statement on the Defence Estimates, Vols. 1 and 2, HMSO, London, 1971-1989.

Steinberg, James B., "Rethinking the Debate on Burden-sharing," *Survival*, Vol. XXIX, No. 1 (January/February 1987), p. 57.

Supply Estimates, HMSO, London, 1971-1989.

Tan, H. W., and M. P. Ward, *Forecasting the Wages of Young Men*, The RAND Corporation, R-3115-ARMY, May 1985.

Thomson, J. A., and N. C. Gantz, *Conventional Arms Control Revisited: Objectives in the New Phase*, The RAND Corporation, N-2697, December 1987.

The United Kingdom Defence Program: The Way Forward, Cmnd. 8288, HMSO, London, 1981.

Vu, My T., *World Population Projections 1984*, World Bank, Washington, D.C., 1984.

Walker, Karen, "Tornado mid-life update set for 1992," *Jane's Defence Weekly*, September 12, 1987, p. 507.

Welch, Finis, "Effects of Cohort Size on Earnings: The Baby Boom Babies' Financial Bust," *Journal of Political Economy*, 87, 1979, pp. S65-S96.

Wettern, Desmond, "RN to lose support ship in MCM force cuts," *Jane's Defence Weekly*, August 29, 1987, p. 368.

Witt, Michael J., "Britain Faces Dilemma in \$2.5 Billion Tank Purchase," *Jane's Defence Weekly*, March 27, 1989.

Witt, Michael J., "Report Estimates \$54 Billion Price Tag for European Fighter Aircraft," *Defense News*, March 28, 1988, p. 36.